S. Hrg. 98-1179

MAGNETOHYDRODYNAMICS AND THE NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACTS

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON

S. 1278

A BILL TO PROVIDE FOR AN ACCELERATED PROGRAM OF RESEARCH, DEVELOPMENT, AND DEMONSTRATION WITH RESPECT TO THE PRODUCTION OF ELECTRICITY FROM MAGNETOHYDRODYNAMICS, LEADING TO THE CONSTRUCTION AND OPERATION OF AT LEAST ONE MAJOR PROOF OF CONCEPT DEMONSTRATION PROJECT IN CONNECTION WITH AN EXISTING ELECTRIC POWERPLANT, AND FOR OTHER PURPOSES

S. 1925

A BILL TO ESTABLISH A NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT PROGRAM

APRIL 9, 1984

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MAGNETOHYDRODYNAMICS AND THE NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACTS

MONDAY, APRIL 9, 1984

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, DC.

The subcommittee met, pursuant to notice, at 10 a.m., in room SD–366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici, Warner, Ford, and Melcher.

Also present: Paul Gilman, professional staff member; James T. Bruce, counsel for the minority; and Linda Mason, professional staff member for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator Domenici. Good morning, everyone.

Today the subcommittee will receive testimony on two bills, Senate bill 1278, introduced by Senator Melcher, on MHD, and Senate bill 1925, introduced by Senator Byrd, concerning the establishment of a National Coal Science, Technology, and Engineering Development Program.

I believe Senator Byrd is here to present testimony for his bill. First, Senator Byrd, let me ask if my colleagues have some opening remarks, and then we will be delighted to hear from you.

Senator Ford.

[The texts of S. 1278 and S. 1925 follow:]

II

98TH CONGRESS
1ST SESSION

S. 1278

To provide for an accelerated program of research, development, and demonstration with respect to the production of electricity from magnetohydrodynamics, leading to the construction and operation of at least one major proof of concept demonstration project in connection with an existing electric powerplant, and for other purposes.

IN THE SENATE OF THE UNITED STATES

MAY 12 (legislative day, MAY 9), 1983

Mr. MELCHER (for himself, Mr. TSONGAS, Mr. STENNIS, and Mr. COCHRAN) introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

---

A BILL

To provide for an accelerated program of research, development, and demonstration with respect to the production of electricity from magnetohydrodynamics, leading to the construction and operation of at least one major proof of concept demonstration project in connection with an existing electric powerplant, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be referred to as the "Magnetohydrodynamics Research, Development and Demonstration Policy Act of 1983".

FINDINGS AND PURPOSES

SEC. 2. (a) FINDINGS.—Congress hereby finds and declares that—

(1) the energy policy of the United States must emphasize the development, as rapidly as is feasible, of a diverse array of technologies capable of using domestic coal efficiently and in an environmentally acceptable manner;

(2) technology for the production of electricity from coal making use of magnetohydrodynamics has the potential for substantially higher efficiencies than can be achieved with other technologies and also promises to meet major environmental requirements applicable to electric powerplants;

(3) commercial acceptance of magnetohydrodynamic technology for the production of electricity will significantly augment the ability of the United States to make use of domestic coal and to reduce its reliance on imported energy, thereby enhancing national security and offering benefits to the Nation as a whole;

(4) although the basic technology of magnetohydrodynamics is available, commercial acceptance of this technology is inhibited by the lack of an adequate Federal program for research, development and demonstration with respect to magnetohydrodynamics;

(5) magnetohydrodynamic technology is ready for a proof of concept demonstration on a scale sufficient to provide reliability and operational data to support commercial evaluation of the technology;

(6) the Federal Government must aggressively support research, development and demonstration of technology for the production of electricity making use of magnetohydrodynamics;

(7) the Federal Government must provide support for the early proof of concept demonstration of magnetohydrodynamic technology in connection with an existing electric powerplant so as to provide reliability and operational data for the technology in a manner that achieves the highest practicable testing and operational flexibility at a cost significantly below the cost of a full-sized demonstration powerplant; and

(8) an adequate program of research, development and demonstration of magnetohydrodynamic technology will require an increased commitment by the Federal Government.

(b) PURPOSES.—The purposes of this Act are to—

(1) establish a definitive Federal program of research, development and demonstration with respect to the technology for producing electricity making use of magnetohydrodynamics;

(2) set forth specific goals for the program, including a target date of 1992 for routine operation in connection with an existing electric powerplant of a proof of concept demonstration facility incorporating magnetohydrodynamic components;

(3) authorize the Secretary of Energy to make financial commitments to, and to enter into a cooperative agreement with private firms for the financing of, a proof of concept demonstration of magnetohydrodynamic technology; and

(4) provide adequate authorization for appropriations for the program established under this Act.

DEFINITIONS

SEC. 3. As used in the Act the term—

(1) "demonstration" includes the addition of magnetohydrodynamic components to an existing electric powerplant in order to obtain operational experience with magnetohydrodynamic technology;

(2) "magnetohydrodynamics" means a system that uses a plasma composed of ionized gases at high temperatures in the presence of an external magnetic field to induce voltages sufficient for the production of electric power; and

(3) "Secretary" means the Secretary of Energy.

ACTIVITIES OF THE SECRETARY

SEC. 4. (a) DUTIES OF THE SECRETARY.—

(1) The Secretary shall conduct and provide support for such research and development as he determines will most expeditiously clarify the scientific and technical issues that directly affect the development and commercial acceptance of magnetohydrodynamic technology.

(2) Research and development under paragraph (1) may include work on—

(A) magnet technology;

(B) instrumentation and diagnostics;

(C) materials properties and behavior under conditions associated with operation of magnetohydrodynamic components;

(D) improved recovery and reprocessing of seed materials added to the magnetohydrodynamic plasma to improve conductivity;

(E) continued improvement of electrodes and channels capable of continuous operation for periods of one year or more;

(F) continued improvement of magnetohydrodynamic combustors; and

(G) such other matters as the Secretary determines will further the purposes of this Act.

(3) The Secretary shall accelerate research and development activities with respect to magnetohydrodynamics under the program in existence on the date of the enactment of this Act.

(b) COMPREHENSIVE PROGRAM MANAGEMENT PLAN.—The Secretary, after consultation with representatives of the electric utility industry, design and construction firms, component suppliers, university and industrial research scientists and engineers, and other appropriate private sector organizations and firms, shall prepare a comprehensive program management plan for the conduct of research, development and demonstration activities under this Act. Such plan shall include—

(1) a presentation of the program strategy that will be used to achieve the purposes of this Act;

(2) a program implementation schedule, including identification of detailed milestone goals and associated budget and program resources requirements;

(3) a discussion of the principal alternative strategies and schedules under paragraphs (1) and (2) respectively and a statement of the reasons why these alternatives were rejected;

(4) a plan for financing the proof of concept demonstration project under section 5;

(5) identification of the supporting research and development needed to solve the scientific and engineering problems likely to arise with magnetohydrodynamic technology in meeting the 1992 target date; and

(6) an analysis of the institutional, environmental and economic considerations that affect the development and commercial acceptance of magnetohydrodynamic technology;

(c) TRANSMITTAL.—The Secretary shall transmit the comprehensive program management plan under this section to the appropriate committees of the House of Representatives and the Senate not later than one hundred and eighty days after the date of the enactment of this Act.

(d) INTERNATIONAL COOPERATION.—The Secretary shall seek to enter into international cooperative agreements for the conduct of magnetohydrodynamic research and development of mutual benefit to the parties to any such agreement that the Secretary determines will further the purposes of this Act.

PROOF OF CONCEPT DEMONSTRATION

SEC. 5. (a) AGREEMENT.—The Secretary shall offer to enter into an agreement in accordance with this section with the owner of an existing, coal-fired, electric powerplant, and with such other persons as the Secretary deems appropriate, for a proof of concept demonstration of magnetohydrodynamic technology in connection with such powerplant. Within two hundred and seventy days after the date of the enactment of this Act, the Secretary shall publish notice soliciting bids for an agreement under this section.

(b) PROVISIONS.—The agreement under paragraph (a) shall provide for—

(1) the construction, operation and maintenance of a magnetohydrodynamic component of capacity of no less than fifty megawatts of electric power in connection with the existing electric powerplant referred to in paragraph (a);

(2) assumption by the Federal Government of no more than 60 per centum of project costs under this section;

(3) a target date of January 1, 1992, for operation of the completed facility; and

(4) disposition of patents and other rights or privileges resulting from the project under this section in accordance with section 9 of the Federal Nonnuclear Research and Development Policy Act of 1974.

(c) COMPETITIVE BIDS.—Within one year after the date of the enactment of this Act the Secretary shall select the parties to the agreement under this section competitively, based on the bids available on the date thirty days prior to selection. In making the award of the selection under this section the Secretary shall weigh and take into account—

(1) estimated project costs to the Federal Government;

(2) the prospects, as determined by the Secretary, for successful completion and operation of the project in accordance with the agreement;

(3) the extent, as determined by the Secretary, to which the project will contribute to the development and commercial acceptance of magnetohydrodynamic technology; and

(4) such other factors as the Secretary deems appropriate.

REVIEW PANEL

SEC. 6. (a) ESTABLISHMENT OF PANEL.—Within ninety days after the date of the enactment of this Act, the Secretary shall establish, and with the concurrence of the Energy Research Advisory Board shall appoint at least seven members to, a Technical Review Panel for Magnetohydrodynamics.

(b) MEMBERSHIP.—Each Member of the panel under subsection (a) shall be a person who by virtue of training and experience is especially qualified to review and comment on magnetohydrodynamic technology in relation to the electric utility industry and to review and comment on the ongoing programs and projects of the Secretary with respect to magnetohydrodynamic technology, including the proof of concept demonstration under section 5.

(c) PROCEDURES.—Activities of the panel under this section shall be in accordance with the laws and regulations, including provisions for compensation, governing activities of technical and fact-finding groups reporting to the Energy Research Advisory Board.

(d) DUTIES.—The panel under this section shall meet at least twice annually and shall review and make such recommendations as the panel deems appropriate on—

(1) the research and development programs of the Secretary with respect to magnetohydrodynamics;

(2) the comprehensive program management plan under section 4(b), the extent to which the plan is being followed and any needed amendments to the plan;

(3) the type of experiments and facilities needed to achieve the purpose of this Act;

(4) the progress in implementing section 5;

(5) the adequacy of cooperation with domestic private industry, including the electric utility industry, and the adequacy of cooperation internationally in research, development and demonstration with respect to magnetohydrodynamic technology;

(6) institutional, environmental and economic factors affecting the development and commercial acceptance of magnetohydrodynamic technology; and

(7) such other matters as the panel deems appropriate.

(e) REPORTS.—The panel under subsection (a) shall report annually to the Energy Research Advisory Board. Such report shall include any recommendations under subsection (d). The Energy Research Advisory Board shall consider each report under this subsection and shall promptly transmit the report along with the comments of the Board to the Secretary and to Congress.

REPORT TO CONGRESS

SEC. 7. As a separate part of the annual report submitted under section 801 of the Department of Energy Organization Act (Public Law 95-91), the Secretary shall submit to Congress an annual report on activities under this Act.

AUTHORIZATION OF APPROPRIATIONS

SEC. 8. (a) AUTHORIZATION.—There is hereby authorized to be appropriated to the Secretary for the fiscal years ending September 30, 1984, September 30, 1985, and September 30, 1986, such sums as may be necessary to achieve the purpose of this Act.

(b) CONTRACTS.—In carrying out the provisions of this Act, the Secretary may enter into contracts only to such extent or in such amounts as may be provided in advance in appropriations Acts.

98TH CONGRESS
1ST SESSION

S. 1925

To establish a national coal science, technology, and engineering development program.

IN THE SENATE OF THE UNITED STATES

OCTOBER 6 (legislative day, OCTOBER 3), 1983

Mr. BYRD introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

---

A BILL

To establish a national coal science, technology, and engineering development program.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Coal Science, Technology, and Engineering Development Act of 1983".

FINDINGS AND PURPOSES

SEC. 2. (a) The Congress makes the following findings:

(1) There is significant potential for the vast domestic coal resources of the United States to play an increasingly important role in the Nation's energy future.

(2) Increased coal use is dependent upon establishing a foundation in coal science which is the basis for all activities leading to process and engineering development and the commercial application of advanced technologies and systems that are consistent with the Nation's environmental goals.

(3) An inadequate foundation in coal science, process science, and engineering development is limiting current efforts to exploit the Nation's vast coal resources.

(4) There must be an accelerated and focused effort to develop and introduce into the marketplace improved and advanced technologies that limit the emissions of sulfur dioxide, nitrogen dioxides, and particulate matter which result from coal combustion. Such efforts must include a broad range of technology options that include pre- and post-combustion treatment, along with combustion modifications, and new and improved combustion technologies to limit sulfur and nitrogen oxide emissions. Waste solid and liquid treatment and disposal must be considered in these technologies to avoid negative environmental impacts.

(5) Current environmental control capabilities must be improved by reducing capital and operating

costs and preserving and improving the overall availability of coal-fired powerplants.

(6) Changes in the domestic economy and changes in environmental requirements, coupled with rapid changes in the supply and price of oil and gas resources, have created significant economic disincentives which preclude the private sector from sustaining a stable long-term research and development program that will enhance expanded coal use. In recent years, both private and Federal support for coal-related research and development has declined substantially which, if allowed to continue, could limit the future availability of coal which can be utilized in an environmentally acceptable manner.

(7) Coal research and development programs in universities and industry tend to focus on the short term due to the lack of adequate funding and tend to be focused on projects with a near-term payback. As a consequence, these efforts generally do not include the more extensive longer term research necessary to develop significant technological improvements or breakthroughs which can enhance the utilization of the Nation's vast coal reserves in an environmentally acceptable manner.

(8) The current thrust of the ongoing Federal coal research and development program is too diverse and is not directed to establishing proof of concept of new and advanced technologies and systems at an engineering-scale size in a timely fashion. This has constrained the timely transfer of technology which, in turn, has constrained the expanded use of coal.

(9) A credible and productive Federal coal research and development program must be defined and sustained for many years. Such a program must be adequately funded, insulated from short-term political and market fluctuations, must be sufficiently broad in scope to produce results, and must be executed in cooperation with both the university community and the private sector.

(10) It is in the national interest for the Federal Government, through its energy technology centers and research contracts with industry and universities, to play a leadership role in accelerating coal science, technology, and engineering development, and to accelerate the development of more efficient and cost-effective conventional and advanced coal combustion and emission control technologies.

(b) The purposes of this Act are to—

(1) promote and significantly expand the use of the full range of the coal resources of the Nation in an environmentally acceptable manner by accelerating research and development in basic coal science and the development and commercial application of more efficient and cost-effective coal utilization technologies and systems; and

(2) expand federally sponsored research and development in a manner that permits a comprehensive, totally integrated, and clearly focused coal research and development program to be implemented in cooperation with the university community and the private sector by establishing a national coal science, technology, and engineering development program.

ESTABLISHMENT OF PROGRAM

SEC. 3. (a) The Secretary of Energy is authorized and directed to carry out a national coal science, technology, and engineering development program as provided in this Act. The program shall be administered by the Assistant Secretary for Fossil Energy.

(b) The national coal science, technology, and engineering development program shall consist of three research and development programs—

(1) the coal science research program as provided in section 4;

(2) the process science and engineering research program as provided in section 5; and

(3) the engineering development program as provided in section 6.

COAL SCIENCE RESEARCH PROGRAM

SEC. 4. (a) The purpose of the coal science research program shall be to conduct research, for all coal ranks, that seeks an indepth understanding of coal structure and process chemistry. The program shall be directed toward the understanding of how pollutant species are bound in the coal molecule and how such species can be efficiently and effectively removed.

(b) The coal science research program shall be—

(1) carried out through the energy technology centers, the national laboratories, the university community, and the private sector; and

(2) administered by the Assistant Secretary for Fossil Energy.

PROCESS SCIENCE AND ENGINEERING RESEARCH PROGRAM

SEC. 5. (a) The purpose of the process science and engineering research program shall be to conduct research, applicable to all coal ranks, in the following areas:

(1) COAL PREPARATION.—Development of new processes that pulverize coal to extremely fine particles

and remove ash, pyritic, and organic sulfur to levels consistent with environmental and equipment uses.

(2) SPECIFICATION FUELS.—Development of ready-to-use and fully characterized transportable coal fuels (for example, coal mixtures) that are suitable for use in various equipment such as boilers and combustion engines. These fuels are to be economically competitive with oil and gas.

(3) PRECOMBUSTION CLEANUP.—Development of new and improved technologies that can clean coal-derived gaseous and liquid fuels prior to use, particularly gas streams at high temperatures, and remove deleterious materials that create pollutants or adversely impact equipment usage. Such technologies shall include necessary supporting analytical and control equipment.

(4) POSTCOMBUSTION CLEANUP.—Development of new and improved processes that will remove sulfur, nitrogen, and ash constituents that result in deleterious emissions. Emphasis shall be given to those processes that are regenerable and will reduce the quantity and improve the quality of disposable byproducts associated with sulfur dioxide scrubbing systems. This effort shall include improvements in state-of-the-art scrubbers to increase system availability and reduce costs. Emphasis

shall also be given to processes that can reduce nitrogen oxide emissions and capture particulates.

(5) UTILIZATION PROCESSES.—Improvement, modification, and development of new processes and equipment that will permit utilization of coal or coal-derived fuel such that pollutant formation and release is well below environmental limits and the resulting integrated system is cost competitive both in terms of capital costs and operational costs. Technologies to be pursued include—

(A) direct combustion of coal for process heat and steam;

(B) atmospheric and pressurized fluidized-bed combustion;

(C) fuel cells;

(D) diesel engines; and

(E) gas turbines.

(6) INSTRUMENTATION AND CONTROL.—Reduction of system operating costs and improvement of system availability by developing new sensors and control systems that will enhance the commercial application of coal utilization technologies and systems.

(7) SUPPORTING RESEARCH AND DEVELOPMENT.—Characterization of the various liquids and solid wastes generated by the use of coal and develop-

ment of processes that will assure the disposal of such wastes in an environmentally acceptable manner. Development of processes that facilitate the cost-effective recovery of raw materials from coal utilization wastes. Materials research shall be conducted to ensure that advanced process concepts can be supported with available engineering materials.

(b) The coal science research program shall be—

(1) carried out through the energy technology centers, the national laboratories, the university community, and the private sector; and

(2) administered by the Assistant Secretary for Fossil Energy.

ENGINEERING DEVELOPMENT PROGRAM

SEC. 6. (a) The purpose of the engineering development program shall be to establish proof of concept and producing developed processes and coal systems at a scale large enough to permit ready commercialization by the private sector. The program shall be structured and implemented to achieve the following objectives within five years of enactment of this Act:

(1) construct a fine coal preparation and cleaning process facility of no more than 500 tons per day (the facility should be constructed in such fashion as to allow the addition of advanced chemical coal cleaning);

(2) retrofit an oil-fired boiler of at least 100 MWe (megawatts electricity) using deeply cleaned coal;

(3) demonstrate a regenerable flue gas desulfurization system of at least 50 MWe;

(4) demonstrate a combined SOX (sulfur dioxide)/NOX (nitrogen oxides) removal system of at least 50 MWe;

(5) conduct a furnace retrofit of in-boiler sulfur control technology of at least 50 MWe;

(6) demonstrate an atmospheric fluidized bed combustion system of at least 100 MWe;

(7) demonstrate a repowering application of a pressurized fluidized bed combustor of from 50 to 100 MWe;

(8) demonstrate a repowering application of combined cycle coal gasification of from 50 to 100 MWe;

(9) develop and test a coal-fueled gas turbine in a second generation combined-cycle system of at least 50 MWe;

(10) develop and test an industrial-scale coal-fueled gas turbine suitable for industrial cogeneration of at least 5 MWe; and

(11) test a utility phosphoric acid fuel cell system using coal-derived gas at a size of 10 to 50 MWe.

(b) The engineering development program shall be administered by the Assistant Secretary for Fossil Energy. The program shall be structured and implemented such that there are sufficient incentives to attract private sector participation. Funds appropriated for the program shall be available on a cost-sharing basis between the Federal Government and non-Federal participants in the program.

FIVE-YEAR PLAN

SEC. 7. (a) As a part of the national coal science, technology, and engineering development program, the Secretary of Energy, with the cooperation of the Assistant Secretary for Fossil Energy, shall prepare a five-year national coal science, technology, and engineering development research plan. The plan shall include—

(1) identification and definition of the near- and mid-term opportunities for expanding the use of coal in the industrial, electric utility, and other sectors of the economy;

(2) a detailed description of the specific activities which have been, or will be, developed by the Department of Energy to address these opportunities and carry out the mandates of this Act;

(3) a statement and explanation of specific priorities and objectives, timetables for achieving such ob-

jectives, and a research strategy for achieving such objectives and the mandates of this Act; and

(4) a detailed description of the resource requirements for the implementation of the plan, and a description of the manner in which those resources will be deployed.

(b) The plan shall be submitted by the Secretary of Energy to the President and the appropriate committees of the Congress within six months of enactment of this Act.

ANNUAL AND FINAL REPORTS

SEC. 8. (a) At the end of each of the five fiscal years after the date of enactment of this Act, the Secretary of Energy shall submit an annual report to the President and the appropriate committees of the Congress. The report shall include a detailed description of the program and activities undertaken for that fiscal year, and the achievements and progress toward the objectives defined in the five-year plan pursuant to this Act.

(b) Within ninety days of the end of the fifth fiscal year after the date of enactment of this Act, the Secretary of Energy shall submit to the President and the appropriate committees of the Congress a report identifying the achievements of the program, and identifying and defining further research needs and opportunities for promoting the expanded use of coal.

AUTHORIZATIONS

SEC. 9. (a) There is authorized to be appropriated for the coal science research program, $75,000,000 to be available for the fiscal years 1985 through 1989.

(b) There is authorized to be appropriated for the process science and engineering research program, $200,000,000 to be available for the fiscal years 1985 through 1989.

(c) There is authorized to be appropriated for the engineering development program, $500,000,000 to be available for the fiscal years 1985 through 1989.

STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator **Ford**. Thank you, Mr. Chairman.

The bills before us today hold a great deal of promise for coal. You are to be commended, Mr. Chairman, for setting up the hearing, and I extend my thanks to you for that.

This committee, in its persistence that coal-burning technology receive attention, has firmly moved the administration off dead center.

The administration is to be commended for the recognition that Congress means business in this area.

This country needs to develop clean coal as an important, if not the most important element toward the achievement and retention of a clean environment. This linkage has too long been neglected.

The administration's fossil fuels budget moves in the right direction. However, I personally believe that it does not go far enough. Much more can be done, and must be done, even in the face of our present fiscal restraints.

Mr. Chairman, hopefully, this hearing can establish a record upon which to base further progress through the appropriation process.

We need to establish a firm policy, I think, in this area. This is primary to the function of Congress, and, basically this committee. And I look forward to the hearings.

I thank you, Mr. Chairman.

Senator **Domenici**. You're welcome, Senator.

Senator Melcher.

STATEMENT OF HON. JOHN MELCHER, A U.S. SENATOR FROM THE STATE OF MONTANA

Senator **Melcher**. Thank you, Mr. Chairman.

Faraday's principle was spelled out in the last century of how to get electricity from an electromagnetic field.

In this century—now late in this century—we're still grappling with how to develop MHD to improve upon Faraday's principle.

Now, we have had first—private sector interest and investment; and, then second, a few years ago we got the Federal Government interested in MHD. The public sector's interest didn't crowd out the private sector. The two started working together, and we seem to be making some strides.

When the Department of Energy made its report to Congress, which is mandated by title 10 of the Department of Energy Organization Act, it said, "MHD, if commercialized, would benefit the Nation's health, safety, and environment. The MHD steam powerplants have the potential to more than meet all the environmental standards, and if they achieve the projected high-operating efficiency, there would be a reduction in atmospheric emissions, coal mining, and water usage per unit of electricity produced."

That last clause needs expanding or, perhaps, clarification.

First of all it says, "* * * if they achieve the projected high-operating efficiency* * *." And that is referring specifically to improving the efficiency of coal burning in producing electricity from 38, 37, or 35 percent efficiency up to 50 percent of efficiency. So MHD would produce 50 percent more electricity per ton of coal.

My second point goes to the reduction in atmospheric emission. Without the use of scrubbers, or very little scrubbing, the air pollution from MHD process would be nonexistent, or extremely negligible.

And then the third point concerns water usage per unit of electricity. Water is very important to us in the West. Because water would not be used in significant quantities in the MHD process it provides a very appealing alternative to traditional ways of burning coal.

So MHD is very inviting. Yet we seem no closer to moving MHD technology toward commercial use now than we did 5 years ago. The hearing today, then, is to see how we get from here to there. The utilization of the MHD process is the real question involved in S. 1278.

I'll be interested in hearing the testimony of the administration, and the testimony of the Department of Energy, and the testimony of those other witnesses on the schedule today.

Thank you very much, Mr. Chairman.

Senator **Domenici**. You're welcome.

Senator Byrd, we're delighted to have you present. We have your written statement. You may proceed as you desire.

STATEMENT OF HON. ROBERT C. BYRD, A U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator **Byrd**. Thank you, Mr. Chairman.

I join with Senator Ford and Senator Melcher in commending you and thanking you for conducting these hearings. I especially thank you for this opportunity to discuss my bill, which is cosponsored by, I believe, about 10 other Senators, the National Coal Science, Technology, and Engineering Development Act, S. 1925.

Congressional interest in and support for the development of coal technology has a long history. In 1961, more than 20 years ago, the Congress established the Office of Coal Research. And in so doing, acknowledged the importance of coal research and development for insuring that the Nation's abundant coal resources can be used economically and in an environmentally acceptable manner.

That was an effort in which I am proud to have played a lead role. The Director of the Office of Coal Research, the first Director, I believe, was a West Virginian, George Shume. And then later he was the Assistant Secretary for Fossil Energy. That was a position, I believe, that was created during the Carter administration at my request.

But the Office of Coal Research was created about 23 years ago. Unfortunately, the advancement of our technological and scientific understanding of coal combustion has been limited.

A 1976 congressional report on the status of coal combustion technology concluded that there had been no significant breakthroughs in such technologies since the late 1920's.

This should be a cause for concern, in view of the fact that direct combustion is the dominant mode of coal utilization.

Electric power generation, for example, accounts for about 84 percent of total U.S. coal consumption. The coal technology issue was again underscored in 1983 by the Electric Power Research Institute.

In congressional testimony, resonant with the insights and hopes of earlier decades, Kurt Yeager, the vice president and director of EPRI's Coal Combustion Systems Division, noted that there's no shortage of opportunities to improve the efficiency, reliability, and environmental performance of coal combustion.

He pointed out that we need a more constructive and coordinated partnership between government and the private sector which would encompass the planning and implementation of R&D as well as the commercial transfer of results.

Unfortunately, in the past few years, the opportunities for such a partnership in coal R&D have been few. The reductions in the Federal budget for fossil energy research and development have not been conducive to establishing such relationships.

In the fiscal year 1985 budget, for example, coal R&D funding is about 70 percent below the fiscal year 1981 level. Programs which focus specifically on developing new and improved technology for direct coal combustion have been significantly reduced.

For example, the DOE fiscal year 1985 request of about $32 million for the Control Technology and Coal Preparation Program is about 21 percent below the 1981 appropriation.

The fiscal year 1985 request of about $32 million for the Combustion Systems Program is about 16 percent below the fiscal year 1981 appropriations.

In light of the perennial environmental challenges to the use of coal, the overall downward trend in DOE's coal research program is unfortunate and unwise.

Despite these critical observations, let me hasten to add that under the leadership of Secretary Hodel a new, more positive attitude toward coal R&D is apparent in the Department of Energy.

There are indications that DOE is more appreciative of the need to address the major constraints to coal use. From my own discussions with Secretary Hodel and with Assistant Secretary Vaughan, it is clear that they are aware of the chellenge to coal use raised by the acid rain debate, and they have played a major role in DOE's renewed interest in coal R&D.

The resolution of this debate will have major consequences for the future of coal utilization in the United States.

It is important to emphasize that the terms of the acid rain debate represent a challenge to the use of all coal, irrespective of whether that coal has a high or low sulfur content, or whether it is mined in Wyoming or in West Virginia.

The simple fact is that there is no coal which is totally free of sulfur and nitrogen. In this regard it is important to note that there's some evidence that acid deposition has been occurring in the West, and this could be the result of man-made emissions of SO_2 from local sources.

Most legislative proposals to control acid rain call for significant reductions in sulfur dioxide and nitrogen oxide emissions, largely from coal-fired powerplants in the Midwest and in the Appalachian regions.

These reductions are over and above those already achieved since the passage of the Clean Air Act. Stringent emission reduction proposals raise a formidable technological challenge to existing powerplants; the emissions of which are not governed by the Clean Air Act's new cource performance standards.

Unfortunately, the range of available options for controlling emissions from older powerplants remains very limited.

To meet the challenge, there must be a Federal commitment to develop, in partnership with the private sector, a variety of advance coal technologies which offer more efficient and economically attractive alternatives to current emission control technology.

There are two principal emissions reduction strategies, each of which entails large costs. The first is to switch to lower sulfur coal. The second is to install flue gas desulfurization equipment; in other words, FGD, or scrubbers, as they are often called.

The first strategy will result in severe economic dislocations in high sulfur coal-producing States. In my State of West Virginia, for example, it has been estimated by the Congressional Research Service that as many as 24,550 coal miners—not necessarily coal miners, but jobs—I assume that's coal mining jobs and associated industry—would be lost in the high sulfur coal-producing region of the State as the result of an 8 million ton SO_2 reduction requirement.

The second strategy will result in a massive capital costs for the installation of scrubbers. This will, in turn, lead to higher electric utility bills.

For example, in West Virginia there are five powerplants which would have to install scrubbers to meet emissions reduction requirements under an acid rain control plan.

These plants account for about 57 percent of the total generating capacity in the State. They also account for about 68 percent of the State's total utility coal consumption.

If these plants, these five plants, had to retrofit scrubbers to control emissions, the capital costs alone would be a little more than $1 billion.

This scrubber, or switching dilemma, can be avoided. A recent report by the Congressional Research Service has pointed out that the delimma is partially the result of a narrow view of potential available technologies for controlling sulfur dioxide and nitrogen oxide emissions from stationary sources.

The report notes that new and advanced coal combustion technologies are available, or will be in a few years, which can offer economic and technical improvements over scrubbers in controlling sulfur dioxide and nitrogen oxides.

This point was recently underscored in a report prepared for EPA by the Ad Hoc Committee to Review the National Acid Precipitation Assessment Program. The ad hoc committee was set up in 1983 to review the work of the Federal acid rain research program established by Congress in 1980.

Among its findings, the ad hoc committee pointed out that control technology is a central component of the acid deposition program, and is currently not included in the Federal acid rain research program.

The ad hoc committee recommended that the Federal funding level for development and demonstration of new control technology should be increased substantially to complement ongoing industry commitments.

The ad hoc committee concluded that the development of new and improved emission control technologies that could be retrofited on existing powerplants, followed by a successful pilot and demonstration-scale testing, is of key importance in the potential long-term mitigation of acid rain.

The National Coal Science, Technology and Engineering Development Act, S. 1925, addressed the technological challenges raised by the acid rain debate.

This bill does not create an entirely new program of research and development. It recognizes the efforts which have been underway in the Department of Energy's coal program.

S. 1925 builds upon and accelerates relevant ongoing activities. It refocuses and integrates such efforts, and concentrates resources for the achievement of specific objectives within 5 years.

By authorizing multiyear funding, my bill provides program stability, and inportant ingredient for a successful coal R&D program.

The bill provides the flexibility for an effective partnership between the Federal Government and the private sector.

Finally, it recognizes that any accelerated program of coal R&D must also involve the university community, and draw upon the scientific and technical resources available through the energy technology centers and the national laboratories.

S. 1925 addresses an important need. It provides the framework for investment in the future of coal use in this country.

I hope that the committee will support the legislation. S. 1925 is an important legislative priority, and I'll be more than happy to offer my assistance to the committee to move the bill through the legislative process.

Mr. Chairman, that concludes my statement. I also have several documents which I would like to submit for the record together with a longer prepared statement. I would be happy to attempt to answer any questions you may have.

Senator DOMENICI. Senator, the additional record inserts will be made a part of the record at this time, if that's your desire.

Senator BYRD. Yes. Thank you.

Senator DOMENICI. And if you have a more detailed statement, it will be made a part of the record at this point.

Senator BYRD. Thank you.

[The prepared statement and additional material submitted by Senator Byrd follow:]

Senator Robert C. Byrd
Testimony before the Subcommittee on
Energy Research and Development
of the Committee on Energy and Natural Resources
on S. 1925, the National Coal Science,
Technology, and Engineering Development Act

April 9, 1984

Mr. Chairman, I thank you for this opportunity to discuss my bill, the "National Coal Science, Technology, and Engineering Development Act" (S. 1925). The purpose of my bill is to establish a five-year program to accelerate the development of new and advanced coal combustion technologies.

Congressional interest in and support for the development of coal technology has a long history. In 1961, more than twenty years ago, the Congress established the Office of Coal Research, and in so doing acknowledged the importance of coal research and development for ensuring that the nation's abundant coal resources can be used economically and in an environmentally acceptable manner. That was an effort in which I am proud to have played a lead role.

Unfortunately, the advancement of our technological and scientific understanding of coal combustion has been limited. A 1976 congressional report on the status of coal combustion technology concluded that there had been no significant breakthroughs in such technology since the late 1920's. This should be a cause for concern in view of the fact that direct combustion is the dominant mode of coal utilization. Electric power generation, for example, accounts for about 84% of total U.S. coal consumption.

The coal technology issue was again underscored in 1983 by the Electric Power Research Institute (EPRI). In congressional testimony resonant with the insights and hopes of earlier decades, Kurt Yeager, the Vice President and Director of EPRI's Coal Combustion Systems Division, noted that there is no shortage of opportunities to improve the efficiency, reliability, and environmental performance of coal combustion. He pointed out that we need a more constructive and coordinated partnership between government and the private sector which would encompass the planning and implementation of R&D as well as the commercial transfer of results.

Unfortunately, in the past few years the opportunities for such a partnership in coal R&D have been few. The reductions in the federal budget for fossil energy research and development have not been conducive to establishing such relationships. In the FY 1985 budget, for example, coal R&D funding is about 70% less than the FY 1981 level. Programs which focus specifically on developing new and improved technology for direct coal combustion have been significantly reduced. For example, the DOE FY 1985 request of about $32 million for the Control Technology and Coal Preparation program is about 21% below the FY 1981 appropriation. The FY 1985 request of about $32 million for the

Combustion Systems program is about 16% below the FY 1981 appropriations. In light of the perennial environmental challenges to the use of coal, the overall downward trend in DOE's coal research program is unfortunate and unwise.

Despite these critical observations, let me hasten to add that under the leadership of Secretary Hodel a new, more positive attitude toward coal R&D is apparent in the Department of Energy. Indeed, there are indications that DOE is more appreciative of the need to address the major constraints to coal use. From my discussions with Secretary Hodel, Assistant Secretary Mares, and Assistant Secretary Vaughan, it is clear that they are aware of the challenge to coal use raised by the acid rain debate, and they have played a major role in DOE's renewed interest in coal R&D.

The resolution of this debate will have major consequences for the future of coal utilization in the United States. It is important to emphasize that the terms of the acid rain debate represent a challenge to the use of all coal, irrespective of whether that coal has a high or low sulfur content, or whether it is mined in Wyoming or West Virginia. The simple fact is: there is no coal which is totally free of sulfur and nitrogen. In this regard, it is important to note that there is some evidence that acid deposition has been occurring in the West, and this could be the result of man-made emissions of SO2 from local sources.

Most legislative proposals to control acid rain call for significant reductions in sulfur dioxide and nitrogen oxide emissions, largely from coal-fired powerplants in the Midwestern and Appalachian regions. These reductions are over and above those already achieved since the passage of the Clean Air Act. Stringent emission reduction proposals raise a formidable technological challenge to existing powerplants, the emissions of which are not governed by the Clean Air Act's New Source Performance Standards. Unfortunately, the range of available options for controlling emissions from older powerplants remains very limited. To meet the challenge there must be a federal commitment to develop, in partnership with the private sector, a variety of advanced coal technologies which offer more efficient and economically attractive alternatives to current emission control technology.

There are two principal emissions reduction strategies, each of which entails large costs. The first is to switch to lower sulfur coal. The second is to install flue gas desulfurization equipment (i.e., FGD or "scrubbers" as they are often called). The first strategy will result in severe economic dislocations in high sulfur coal-producing states. In my state of West Virginia, for example, it has been estimated by the Congressional Research Service that as many as 24,550 jobs would be lost in the high sulfur coal-producing region of the state as the result of an 8 million ton SO2 reduction requirement.

The second strategy will result in massive capital costs for the installation of "scrubbers." This will, in turn, lead to higher electric utility bills. For example, in West Virginia there are five powerplants which would have to install scrubbers to meet emissions reduction requirements under an acid rain control plan. These plants account for about 57% of the total generating capacity in the state. They also account for about 68% of the state's total utility coal consumption. If these plants had to retrofit scrubbers to control emissions, the capital costs alone would be a little more than $1 billion.

This "scrubber-or-switching dilemma" can be avoided. A recent report by the Congressional Research Service has pointed out that the dilemma is partially the result of a narrow view of potentially available technologies for controlling sulfur dioxide and nitrogen oxide emissions from stationary sources. The report notes that new and advanced coal combustion technologies are available, or will be in a few years, which can offer economic and technical improvements over scrubbers in controlling sulfur dioxide and nitrogen oxides.

This point was recently underscored in a report prepared for EPA by the "Ad Hoc Committee to Review the National Acid Precipitation Assessment Program." The Ad Hoc Committee was set up in 1983 to review the work of the federal acid rain research program established by Congress in 1980. Among its findings the Ad Hoc Committee pointed out that control technology is a central component of the acid deposition problem and is currently not included in the federal acid rain research program. The Ad Hoc Committee recommended that the federal funding level for development and demonstration of new control technology should be increased substantially to complement on-going industry commitments. The Ad Hoc Committee concluded that the development of new and improved emission control technologies, that could be retrofitted on existing powerplants, followed by successful pilot and demonstration-scale testing, is of key importance in the potential long-term mitigation of acid rain.

The "National Coal Science, Technology, and Engineering Development Act" (S. 1925) addresses the technological challenges raised by the acid rain debate. My bill does not create an entirely new program of research and development. It recognizes the efforts which have been underway in the Department of Energy's coal program. S. 1925 builds upon and accelerates relevant on-going activities. It re-focuses and integrates such efforts, and concentrates resources for the achievement of specific objectives within five years. By authorizing multi-year funding, my bill provides program stability, an important ingredient for a successful coal R&D program. My bill provides the flexibility for an effective partnership between the Federal Government and the private sector. Finally, it recognizes that any accelerated program of coal R&D must also involve the university community, and draw upon the scientific and technical resources available through the Energy Technology Centers and the National Laboratories.

S. 1925 has the following major elements:

1. It establishes a five-year program to accelerate the development of a range of technologies to allow the use of coal in an environmentally acceptable manner. The program would focus on three areas:

    A. Coal Science: This would involve a comprehensive effort to understand coal's structure and chemistry. Of particular concern would be an understanding of how pollutants are bound in coal molecules and how they can be removed efficiently and effectively.

    B. Process Science and Technology: This would involve a comprehensive research program to develop new and advanced technologies for coal preparation, clean combustion, and post-combustion cleanup of flue gases. It would also develop advanced utilization processes, such as fluidized-bed combustion, fuel cells, and diesel engines and gas turbines that use coal.

    C. Engineering Development: This would be a broadly based effort carried out in conjunction with the private sector. The program would be directed to establish proof-of-concept and produce, within five years, processes and coal systems at a scale large enough to permit ready commercialization by the private sector. This effort would involve significant cost-sharing between the federal and non-federal participants. It would concentrate on such technologies and approaches to emissions control as advanced coal cleaning, atmospheric and pressurized fluidized-bed combustion, advanced flue gas desulfurization technologies, and SO2 and NOX removal systems.

2. The bill would establish a leadership role for the Federal Government by which the Department of Energy would work through the Energy Technology Centers, and through research contracts with industry and universities, to accelerate the development of advanced and improved coal combustion technologies.

3. The Assistant Secretary for Fossil Energy of the Department of Energy would be responsible for administering the program.

4. S. 1925 requires the preparation of a five-year research plan which would be submitted to the President and the appropriate committees of the Congress. The five-year plan would show how the program is to achieve the objectives of the Act.

5. My bill provides an authorization for funding for the program over a five-year period at a level of $775 million.

S. 1925 addresses an important need. It provides a framework for investment in the future of coal use in this country. I hope the Committee will support this legislation. S.1925 is an important legislative priority, and I will be more than happy to offer my assistance to the Committee to move the bill through the legislative process.

Mr. Chairman, that concludes my statement. I also have several documents which I would like to submit for the record. would be happy to answer any questions you may have.

SUBMIT FOR RECORD

WEST VIRGINIA
SELECTED POWERPLANTS:
ESTIMATED CAPITAL AND ANNUAL COSTS OF LIMESTONE FGD SYSTEMS
($ 1980)

PLANT	CAPITAL COSTS ($MILLIONS)	ANNUAL COSTS ($MILLIONS)
AMOS	$ 317.00	$ 101.00
FT. MARTIN	136.00	43.00
HARRISON	251.00	76.00
KAMMER	126.00	43.00
MITCHELL	216.00	71.00
TOTAL	$1,047.00	$334.00

SOURCE: U.S. DEPARTMENT OF ENERGY, ACID RAIN: CONTROL STRATEGIES FOR COAL-FIRED UTILITY BOILERS (MAY, 1982, VOL. I, TABLE 3-10, PP. 3-40.

DEVELOPING THE OPTIONS FOR EMISSIONS CONTROL

Today's options for reducing power plant emissions are costly and limited. R&D efforts are attempting to broaden the field of choice and improve the cost-effectiveness of pollution control.

Control strategies aimed at reducing power plant emissions have shifted in the last decade from a focus on new plants to a concern over existing plants. The Clean Air Act of 1971 established tight federal standards on the combustion emissions of new plants with the assumption that as older plants were retired, their replacements would constitute a higher and higher percentage of utility generating capacity. However, with rising capital costs and a sharp reduction in historical load growth, plant turnover has stalled, sparking renewed legislative and regulatory efforts toward increased controls on pre-1971 plants.

This recent push introduces a fundamental choice of investment strategies for decision makers—whether to increase the investment on older, less-efficient plants where controls are not an integral part of the design or to reserve investment capital for systems now under development that combine superior environmental performance with improved energy and operational efficiency.

In response to the current politically charged issue of acid rain, proposed legislative and regulatory action has targeted coal-fired plants because of their large role in SO_2 emissions. Collectively, they exhaust about 14.4 million tons of SO_2 each year—91% of the total from utility plants of all kinds and about 60% of what comes from all man-made sources in the United States. Coal-fired plants are also a significant source of NO_x, although the greatest percentage comes from cars and trucks. The annual volume of 4.6 million tons from coal-fired plants is 82% of all utility NO_x and almost a quarter of the NO_x from all U.S. sources.

Whether or not widespread action is taken against coal-fired plant stack emissions, no single solution is expected to satisfy the widely varying fuel and design conditions of existing coal-fired plants. There are several basic control approaches and any number of technical variants under development or in use today. They encompass restricted plant operation; the use of different or cleaned coals; altered firing practices, burners, and combustion conditions; and the introduction of reagents to inhibit or capture pollutants in combustion gases.

Plant retirement is not a process or hardware control, but it does have a direct effect on emissions. Of course, this option implies an investment in replacement power and, depending on its source, the continued emission of SO_2 and NO_x at some level.

The same is true of a less drastic step, environmental dispatch: plant use only when weather conditions mitigate the transport and conversion of SO_2 and NO_x. The usual practice is economic dispatch, responding to increased demand with the unit or plant that generates electricity most cheaply among all those available. Therefore, environmental dispatch would imply higher operating costs.

Both of these options are likely to be choices of last resort, when site-specific analyses show that process or plant changes are impossible or uneconomic. Retirement and environmental dispatch re not inherently cheap options; they nean forgoing the recovery of some por- on of a plant's capital cost. In addition, both may affect the reliability of ctricity supply and hence be unaccept- ble to utility regulatory bodies.

Other alternatives, such as coal switch- ng and cleaning, modification of com- ustion process and equipment, and ostcombustion exhaust treatment, turn o technologic advances to achieve their oal. But even aside from differences in heir development status, these options re not interchangeable in application.

In the first place, they differ signifi- antly in how much SO_2 and NO_x they re capable of removing. This is illustrated by the broad range between 5–10% O_2 removal at the low end of coal clean- ng to over 90% removal at the high end f flue gas desulfurization. Even the ret- ofittable combustion measures for NO_x eduction range from 5–10% to more than 0% removal.

The second point is that capital and op- rating costs do not neatly match the pro- ression of pollutant removal efficiency. e is a sharp change in the curve of ost-effectiveness (cost per ton of pollut- nt removed) for SO_2 control, and per- ormance above about 35% SO_2 capture ecomes disproportionately expensive.

The third obstacle to interchangeabil- ty of emission control options is the reat number and variety of functional riteria that determine their applicability: uel type, plant design, furnace geometry, omponent capacities, duct configura- ion, land area, water availability, and nany others.

Because the technology options are not nterchangeable for the three reasons ited, direct comparison of options based n a specific factor is not useful. Rather, ach technology is important because of s combined score, actual or potential, in erformance, cost, and applicability to oday's coal-fired power plants.

oal switching

basic approach to emissions control ves simply altering the fuel that is burned in a plant through switching, blending, or cleaning. Changing the source of incoming coal, referred to as switching, may involve relatively little capital outlay and outage time by a utility. This is why it is potentially important among the apparent, quick fixes for acid rain.

In addition to its potential for SO_2 control, switching fuel has historically been a way to improve combustion properties—to deal with variable or declining coal quality and still maintain consistent grindability, heat rate, slagging potential, ash production, and so on.

As a matter of emissions control, coal switching means substituting for one raw coal or blending it with another that has a higher sulfur content. The practice can cut emissions by 30–80%, depending on the blend, but it has several major ramifications. One, obviously, is cost. Low-sulfur blending coal typically carries a price premium of up to 30%; but if coal switching becomes so popular that it creates heavy competition for low-sulfur sources, that premium could increase significantly. Also, when low-sulfur coal is transported a long distance from its southern Appalachian or western source, transportation cost can account for three-fourths of its delivered price.

Another issue is the impact on overall plant operability of burning a grade of coal for which the plant was not designed. For most U.S. utility boilers, severe fuel changes may require lowered temperatures, degraded heat rates, reduced generating capacities, and major modifications to the electrostatic precipitator used for particulate emissions control. Blending in lower-sulfur coal therefore involves plant-specific analyses to maintain economical and reliable plant performance. In some instances where plants were designed to burn high-sulfur midwestern coal, blending in more than 30% of a low-sulfur western coal, with its fundamentally different ash composition, can produce intolerable slagging and fouling unless the plant is operated at less than its rated capacity.

From a technical standpoint, coal blending and switching for SO_2 reduction are attractive and broadly applicable. But there remain awkward conflicts that center on regional economics and politics. For example, switching to low-sulfur fuel that must be shipped long distances could have a major impact on the local coal supply industry, particularly in northern Appalachia and the Midwest. Such an abrupt change could put thousands of local people out of work. Long-term take-or-pay coal supply contracts would have to be renegotiated and penalties paid where past decisions no longer fit future plans.

The technical attractiveness of coal switching is therefore in check until institutional agreements make possible its broad use. In the meantime, switching is likely to involve no more than about 50 million tons annually, potentially reducing SO_2 emissions by about a million tons. The necessary capital equipment is estimated to cost $40/kW and the low-sulfur coal to carry a premium of $15–$20 a ton.

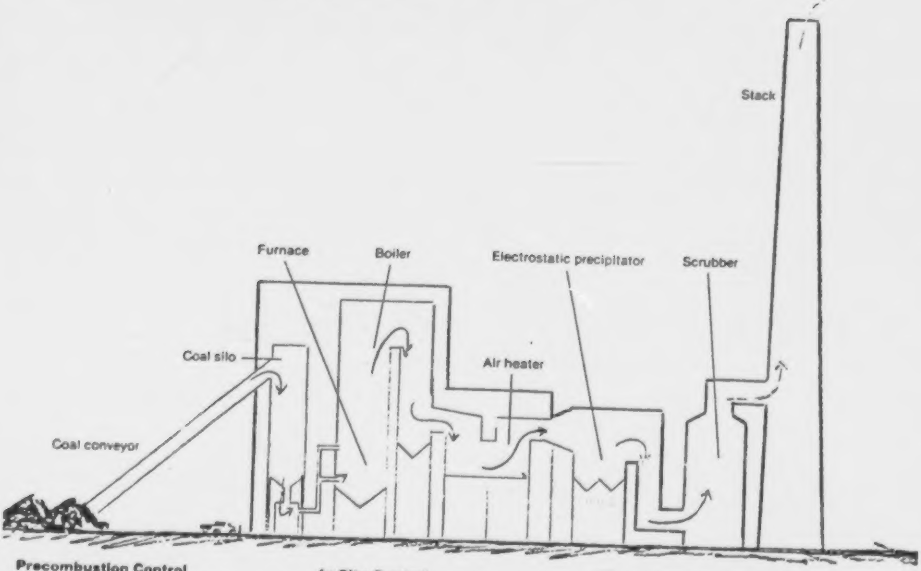
Coal cleaning

Coal cleaning is another way to alter the quality of the fuel stock for better emission characteristics. The process was once a special treatment restricted to fuels used in high-value industrial processes, such as steelmaking. It has come to be economically feasible for steam coal as a means of reducing transportation costs and of improving firing properties by reducing the ash and inorganic (pyritic) sulfur content.

Today's coal beneficiation is categorized as physical coal cleaning. Coal is crushed to break apart the particles of coal and impurities. Further processing takes advantage of the different specific gravities of coal and mineral impurities to separate them in a liquid medium. This can reduce the sulfur content of many northern Appalachian and midwestern high-sulfur coals by 30% or more. Chemical cleaning, while potentially capable of higher sulfur removal, is far from ready for use, and early estimates show it to be very expensive; it is not likely to be suitable for com-

Cleanup Along the Fuel Path

A wide variety of alternatives are available for reducing SO_2 and NO_x emissions from fossil-fuel-fired power plants. The choices can be roughly grouped according to where they are applied along the fuel path—before, during, or after combustion.



Precombustion Control

Options for emission reduction begin outside the power plant with fuel change—outright switching, blending, or cleaning coal to lower the incoming sulfur content. These options are limited in terms of sulfur reduction, partly by the processes themselves and partly by the narrow range of fuel characteristics that utility boilers are designed to accept; but they entail the least capital investment and are far and away the most cost-effective.

In Situ Control

Several new technology options focus on the power plant boiler, where changes in the combustion process itself can suppress the formation of pollutants or capture them before exhaust gases proceed through the rest of the system. These changes are dictated by the configuration of equipment and the manner in which coal and combustion air are combined Notable examples are low-NO_x burners, the fluidized bed for burning coal in the presence of limestone, and the injection of limestone into the furnace.

Postcombustion Control

The best-known SO_2 emission control is postcombustion treatment—flue gas desulfurization in scrubbers just ahead of the power plant exhaust stack. Scrubbers are capable of high performance in SO_2 removal, but they are expensive as retrofit equipment because of installation cost and provisions for their reliable operation. R&D addresses this problem and also explores other postcombustion exhaust treatments.

mercial application in the utility industry unless its cost can be reduced substantially.

Even when it is regarded only as a means to reduce SO_2 emissions, coal cleaning is attractive for two main reasons. One is that it requires only minimal power plant modification; the other is that it may lead to a number of collateral benefits. With reduced ash and sulfur content, clean coal costs less to transport and causes less wear and tear on pulverizers and other coal-handling equipment. It imposes less burden on ash removal and flue gas cleanup systems, and its firing properties may be better (higher Btu content and generally reduced potential for fouling and slagging).

Even today, about one half of high-sulfur utility coal is cleaned to some degree, primarily for economic reasons. Much more could be cleaned, however. An EPRI assessment based on cleanability analyses by DOE and the Bureau of Mines suggests that SO_2 emissions could be cut by about another 1.5 million tons annually in this manner, concentrating on high-sulfur coals amenable to this approach. The effort would involve capital costs of about $40/kW, affecting 100 million tons per year of high-sulfur northern Appalachian and Midwest coal production. The overall yearly cost might thus be $1 billion.

Although coal cleaning is cost-effective for what it offers, under most legislative proposals it could be only a partial solution. Still, cleaning would reduce the level of performance required of other emissions control hardware installed at the power plant.

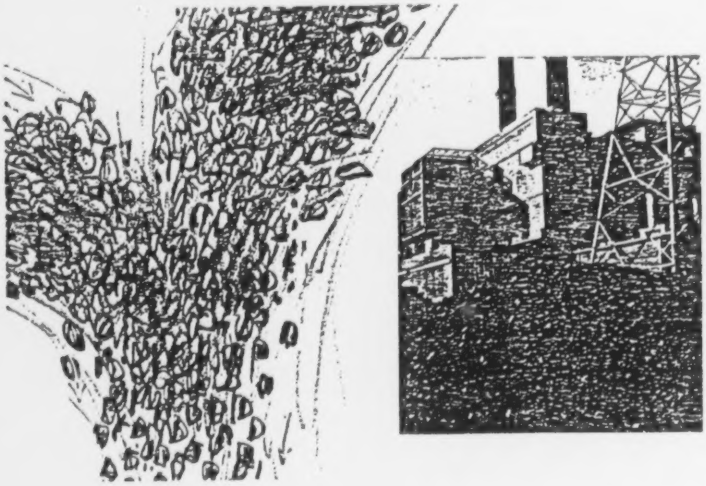
The focus of R&D and testing of various physical cleaning methods and their applicability to different coals is the two-year-old Coal Cleaning Test Facility, conceived and cosponsored by EPRI at Homer City, Pennsylvania. Research there is aimed particularly at the qualities of coal as an electric utility fuel.

Despite utility interest in coal-cleaning technology, in most instances utilities will continue to buy their coal, cleaned or otherwise, from a fuel supplier. For the utility user, therefore, clean coal carries a market-controlled price rather than a technology-controlled cost, and that fact will figure prominently in economic decisions about this option for emissions reduction. The present incremental cost for coal cleaning is in the range of $4–$9 per ton of clean product coal; the incremental price to the user for cleaned coal, on the other hand, is typically $6–$12 per ton.

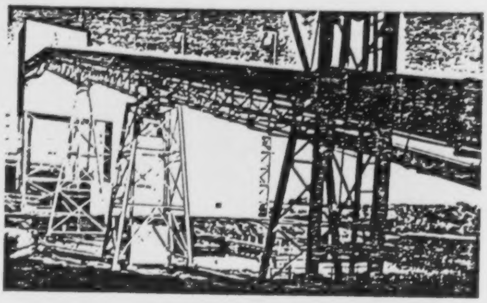
Flue gas desulfurization

Feed stock modifications, such as coal switching or cleaning, can contribute a significant reduction in power plant emissions, but they are solutions that are external to the plant itself. To achieve the higher SO_2 and NO_x removal levels in some proposed legislation, utilities will almost certainly have to turn to internal options—modifications in the plant itself or new processes for cleaner combustion.

Today, flue gas desulfurization has to lead the list of commercially available plant emissions control options. Flue gas scrubbers exist and have been made to work by the utility industry, removing at least 90% of the SO_2 emissions from



Coal Blending
Changing coal can be as drastic as a complete switch to a low-sulfur source. But to maintain practical combustion and handling properties, the more likely solution is a blend of high- and low-sulfur coals. Widespread changes in fuel mix could have important implications for patterns of coal demand and supply across the country.



Coal Cleaning

Separating coal from mineral matter takes advantage of different specific gravities, as coal particles are floated or centrifuged free from the ash, which is heavier. Because clean coal is cheaper to transport and burns more evenly, EPRI's Coal Cleaning Test Facility seeks more economical and thorough separation processes.

high-sulfur-coal combustion on new plants. This has important implications for entire regions of the United States that are fueled by such coal. As noted in connection with coal switching, the coal, electric power, and other industries in those regions are economically interdependent to such a degree that there is great incentive to make practical use of local coals. Flue gas desulfurization provides one solution to the problem.

In this process, the flue gas produced in coal combustion is typically sprayed with a slurry made up of water and an alkaline reagent—usually lime or limestone. The SO_2 present in the flue gas reacts chemically with the reagent in the slurry, forming calcium sulfite and/or calcium sulfate, which is removed and disposed of in the form of a wet sludge.

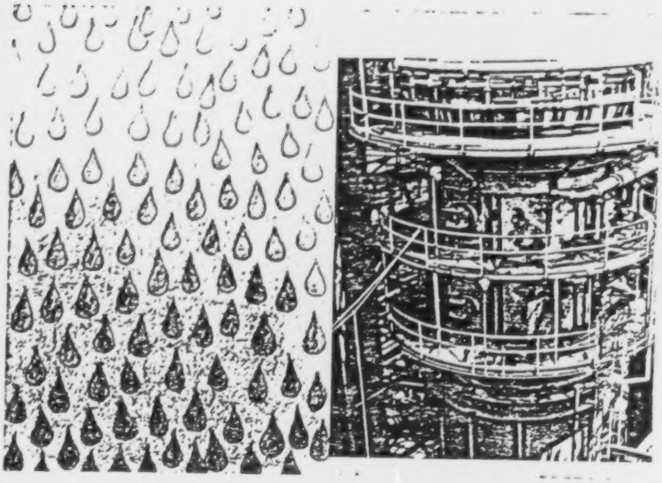
Although wet scrubbers offer large percentage reductions in sulfur, they are usually the least cost-effective control in terms of cost per ton of SO_2 removed. At high removal rates, this means high capital cost, especially undesirable for a retrofit item that may have to be squeezed into place in an older plant with limited remaining life. In a new power plant, the scrubber will commonly cost $140–$175/kW. In a retrofit application, it typically costs 10–40% more, but this premium may be as high as 110%.

High cost derives from more than design and construction. Scrubbers yield large volumes of wet waste, thereby requiring extensive land area for ponds or landfills (or, alternatively, expensive transportation for waste disposal elsewhere). Scrubbing uses huge amounts of water (500–2500 gal/min [0.03–0.16 m^3/s] for a 500-MW plant), and many processes still have problems with plugging and fouling of the equipment and corrosion of fans and ductwork downstream, matters that add to operating costs and cut away at reliability. Finally, scrubbers extract a penalty of about 3–8% of plant output energy, simply to run pumps, fans, and flue gas reheat systems.

Scrubber R&D focuses on better reliability, lower cost, and less waste. In the shorter term, redundant components (which can be brought into service while others are down) have boosted average high-sulfur-coal scrubber availability by 20–25 percentage points in the last five years, to a current range of 80–90%.

Reliability comes from better process chemistry and simplified equipment. One new scrubber configuration, for example, increases the contacting (of SO_2 molecules and scrubber reagent) by bubbling the flue gas through the reagent slurry instead of spraying the reagent slurry into the flue gas stream. The scrubber consumes less energy because the scrubbing liquor need not be pumped through spray nozzles. Also, its chemistry yields a relatively dry gypsum waste that is potentially marketable.

Another variant in both configuration and chemistry, the double alkali scrubber, absorbs SO_2 from the flue gas with a clear aqueous solution, usually sodium sulfite, so as to minimize the scale and plugging problems that can plague conventional lime or limestone slurry scrubbers. Lime or limestone in the recirculating tank fixes the sulfur in solid form for disposal. Double alkali scrubbing successfully mini-



Flue Gas Desulfurization
Lime or limestone in a finely sprayed slurry is the standard shower bath that scrubs SO_2 from power plant flue gases today. Stainless steel vessels like this one — equivalent to 100 MW of plant capacity — use multilevel sprays to remove more than 90% of the sulfur from high-sulfur coal combustion gas.

mizes scale and is being applied to high-sulfur combustion gases.

Another advanced concept, spray-dry scrubbing, is of special interest because of its suitability for retrofit applications, where equipment size and water availability may be special problems. In this option, the reagent (usually lime) slurry is injected into an absorber vessel in finely atomized form; the droplets evaporate in the hot gas, leaving only dry, reacted particles for collection by conventional baghouses or electrostatic precipitators. The simplicity of the process lends reliability and economy to spray drying, and the waste may be easier to handle than that from wet scrubbing.

In an overall assessment, there is much to be said for flue gas desulfurization. It is an established technology for high-efficiency SO_2 removal and can be used in new or retrofit applications. In fact, FGD is the only technology that currently can satisfy federal emission standards for new plants. However, its high cost is a blem that is likely to become an even greater handicap in the future. Its application to existing plants is an expensive add-on solution, extending the life of these older, relatively inefficient units rather than encouraging their replacement by newer technology.

For a decade scrubbers have been in the position of being the only devices that can produce major reductions in high-level sulfur emission; soon, as new technologies are developed that—alone or in combination—can compete technically, the cost of FGD will have to be reduced if it is to compete economically.

Low-NO_x combustion

NO_x is formed in the furnace from nitrogen in both the coal and the combustion air. The chemical reactions involved depend strongly on the rate of fuel-air mixing and on the resultant temperatures in and around the flame zone. NO_x formation is thus encouraged or inhibited by firing practices, burner design, and furnace geometry. All are important because man-made NO_x emissions, unlike those of SO_2, are projected to increase in coming years.

Three combustion modifications are most attractive for coal-fired boilers: low-excess-air combustion, overfire air ports, and low-NO_x burners. All are ways to control the amount of oxidant made available in the combustion process and limit its peak temperature, essentially by the timing and location of air injection.

Low-excess-air operation is a change that can yield up to 15% lower emissions for a very small capital cost—about \$0.40/kW. Overfire air ports can reduce NO_x as much as 30–50%, depending on how the burner pattern shapes the flame zone, at a capital cost of about \$2/kW. However, only a limited range of boilers can be modified for these options.

The technology under development that is expected to be least affected by such limitations is the low-NO_x burner. This device differs from conventional burners in that it delays the mixing of fuel and air in the boiler. Such control creates a very fuel-rich mixture in the combustion zone that limits formation of NO_x from nitrogen bound in the coal molecules.

Low-NO_x burner designs are being pursued for all four of the basic furnace types now in utility use. Although they seem to be more amenable to use with some systems than others, it is expected that low-NO_x burners will be a retrofit option for a majority of U.S. coal plants. On the basis of pilot-scale testing with U.S. coals, the NO_x reduction capability and capital cost of some advanced burners are projected at about 45–60% and $8–$16/kW, respectively.

Firing practices and burner designs are clearly the main candidates for retrofit improvements. Altering the furnace itself is a matter of replacement, not retrofit. Even so, furnace configuration remains important in assessing the applicability of other combustion modifications. EPRI is therefore inventorying utility boilers according to such factors as rating, age, firing pattern, burner type, manufacturer, and coal. The data are expected to provide solid information on the nationwide potential for reduction of utility NO_x emissions.

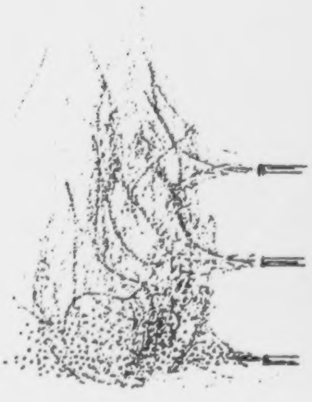
It is estimated that about 60% of U.S. coal-fired capacity (units of 100 MW and larger) is retrofittable in some way to reduce NO_x emissions. But only about 38% can foreseeably use the low-NO_x burners now commercially available or under development. The R&D incentive is to close that gap with a full range of combustion staging devices.

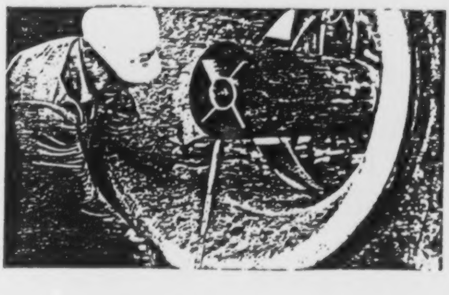
NO_x can also be removed from flue gas with very high efficiency, but the principal scheme, called selective catalytic reduction (SCR), does not appear economically attractive. Capital cost alone, for example, appears to be 10 times that of combustion modification to suppress NO_x. Also, high temperature requirements of the process require the SCR equipment to be immediately adjacent to the boiler itself, upstream from the furnace air heaters and particulate removal equipment, whose functions are affected by the SCR byproducts. These problems appear technically surmountable, but the high capital and operating costs of the process do not provide an incentive to do so.

Furnace limestone injection

Attempts to capture SO_2 by injecting limestone into the furnace date from the 1960s, but because the process chemistry was not well understood or controlled, it was ineffective. The potential costs of retrofit SO_2 control call for a second look at limestone injection, as does the finding that favorable furnace conditions for the process may be similar to those required for suppression of NO_x formation. Within the past five years, therefore, the research goal has become one of developing a single technology capable of significantly reducing SO_2 and NO_x simultaneously.

In this process, dry pulverized limestone ($CaCO_3$) is fed into the furnace, where it calcines to lime (CaO) and reacts with SO_2 to form dry, solid calcium sulfate ($CaSO_4$), or gypsum. These reactions are now known to proceed most effectively in gradual combustion at reduced temperature, which is a desirable environment for NO_x suppression. By contrast, a conventionally hot, high-heat-release flame zone seems to fuse and seal





Low-NO_x Combustion
NO_x is an inherent combustion product because nitrogen comes from the combustion air as well as from the coal itself. Reduced flame temperature and slower combustion are key mechanisms of NO_x suppression. Retrofit burners feature coal pipe and air passages shaped to lengthen the flame zone by the relatively gradual introduction and mixing of air.

sinter) the limestone particles, cutting off their reactivity. This fundamentally imited the effectiveness of the earlier atmpts at SO_2 reduction by this method.

EPA has sponsored development of a combustion configuration called the limestone injection multistage burner (LIMB), which combines the features needed for both SO_2 and NO_x control. EPA's target for SO_2 removal alone is 50–70%; work o date has been limited, however, to aboratory-scale research. In a separate development, Japanese researchers have ested limestone injection at pilot scale with low-NO_x burners and achieved as much as 50% SO_2 removal.

Meantime, other tests show a range of 20–50% SO_2 removal, this performance variation being largely a function of limestone injection rate (as well as combustion conditions) and thereby closely controllable. Cost-effectiveness draws attention to the technology, completely apart from the implications for NO_x control. It appears capable of 40–60% SO_2 capture, roughly half that of a lime/limestone scrubber. Capital cost may be only $15–/kW, one-tenth to one-quarter of scrubber cost. The operating cost advantage is not as striking; the much larger quantity of limestone required results in a busbar electricity cost impact typically about half that of a wet scrubber.

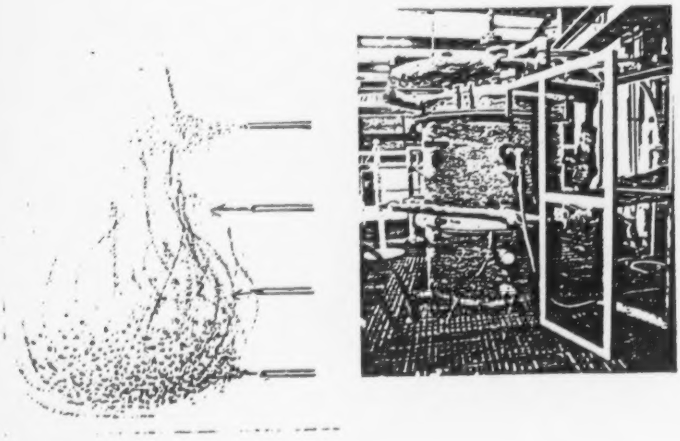
Limestone mass also causes a technical problem. It results in a high loading of solid particles in the flue gas, which could alter slagging and fouling behavior, produce erosion in the convection zone of the boiler, cause plugging of air heaters, and easily double the task of baghouse or precipitator, where the calcium sulfate particles are collected. The ash handling and disposal system could also be overloaded. Modifications necessary to resolve these problems can add substantially to the cost of installation. Although the possibility of improved SO_2 removal exists when the process is used in conjunction with low-NO_x conditions, the fouling, erosion, and corrosion problems that plagued earlier attempts at limestone injection remain to be resolved before commercially acceptable reliability can be assured.

A 300-MW demonstration by a German utility began nearly a year ago, and a 700-MW demonstration by a German boiler manufacturer is planned to start by the end of 1983. The latter incorporates a low-NO_x burner. Both programs seek SO_2 removal better than 60%, but such results, even if achieved, will not be directly transferable to U.S. experience because of differences in furnace designs and coal properties. German coal, for example, contains 1% or less sulfur, substantially reducing the limestone loading relative to U.S. high-sulfur coal, which contains 2–4% sulfur or more.

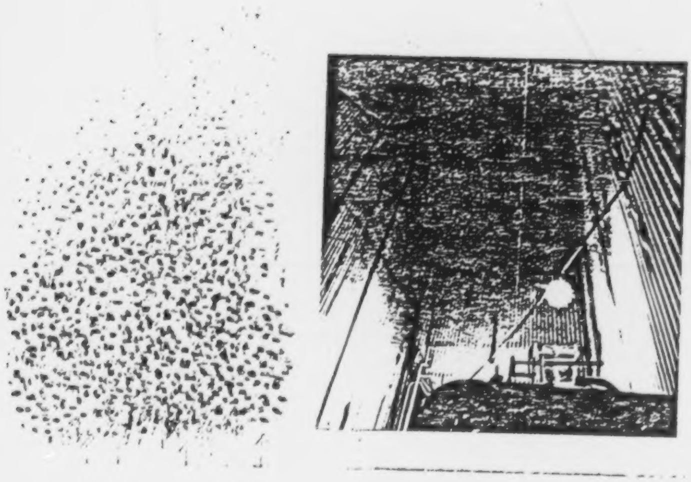
Taking full advantage of the German and Japanese results, and also of LIMB and other concepts for combined emissions control, EPRI-sponsored development of furnace limestone injection is planned to include laboratory work through 1984, prototype testing at 20–100 MW in 1986, and if successful, the startup of a 400-MW or larger utility demonstration in 1988.

Fluidized-bed combustion

Fluidized-bed combustion (FBC) is important because of its inherently low SO_2 and NO_x emissions. The technology is



Furnace Injection of Limestone
Finely pulverized limestone can capture SO_2 from the gases in a conventional furnace when combustion conditions are controlled to suppress NO_x. Such combined reduction of boiler emissions is the subject of international R&D that ranges from pilot-scale combustor experiments to full-scale boiler tests.



Fluidized-Bed Combustion
Both SO_2 and NO_x emissions are curtailed in a fluidized combustion bed, where upwelling air suspends the burning coal among limestone particles. Rapid heat exchange holds the temperature down to suppress NO_x, and the churning limestone captures SO_2 as $CaSO_4$. Process development is moving from 20-MW pilot to 140-MW demonstration scale, and boiler retrofit criteria are being carefully considered.

not yet commercial at large-utility scale, but a 160-MW demonstration by EPRI with TVA, Duke Power Co., and the state of Kentucky will begin construction by 1985 at TVA's Shawnee station, near Paducah, Kentucky. Other utility demonstrations in the 100–200-MW range are also being considered.

The technology features a special furnace configuration in which a mixture of fuel and limestone is suspended and churned about in an upwelling flow of air. In terms of weight, the fluidized-bed particles exceed the fuel particles by 99:1, improving and stabilizing the heat transfer. Steam generator tubes are submerged directly in the fluidized bed, and heat exchange there is more efficient than at the water walls of a conventional boiler.

Just as with limestone injected into a pulverized-coal furnace, the limestone of a fluidized bed reacts to capture the evolving SO_2—in this case, 90% or more. Combustion can be maintained at about 1500°F (816°C), instead of twice that figure, which precludes slagging and also inhibits NO_x formation. This results in a design that has much greater fuel flexibility, thus reducing dependence on expensive high-quality coal.

The feasibility of converting existing pulverized-coal boilers to FBC offers an attractive opportunity to reduce emissions while providing increased fuel flexibility and generating capacity. EPRI studies furnish examples. Analysis of a 500-MW boiler six years ago showed that the cost of furnace modification then (including the outage time to do it) was greater than the cost for adding a retrofit scrubber.

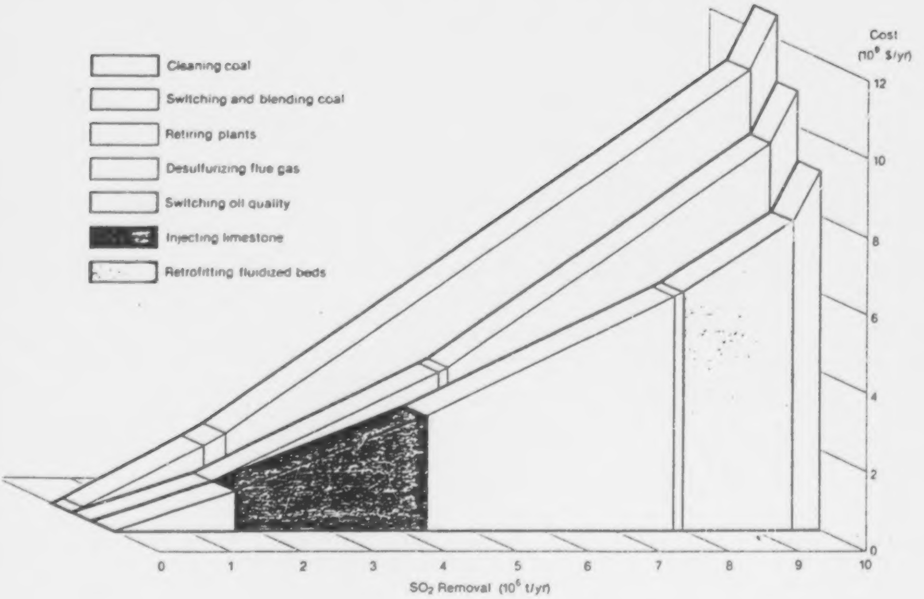
Since then, however, changing cost conditions plus improvement in FBC technology have led to reexamination of this option. Another boiler is now being studied that may benefit from these different circumstances. To cut SO_2 emissions, this 100-MW pulverized-coal unit on the Northern States Power Co. system was switched from an eastern bituminous to a low-sulfur western coal. The lesser heating value of the new fuel has forced a unit derating to 85 MW. Analysis is now under way to establish whether this boiler can be practically retrofitted with a fluidized bed to restore or even exceed the original 100-MW rating.

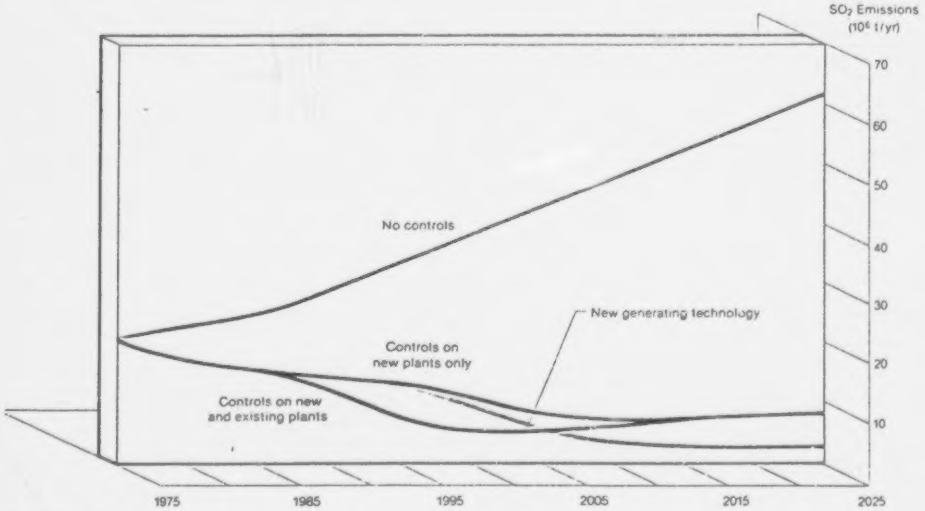
The key technical difference in these two cases appears to be the physical size of the boiler relative to its rated capacity. The 500-MW boiler was a late 1960s product, tightly designed for economy and therefore small, with a high heat release rate. The 100-MW boiler dates from the 1950s; it is a looser, more-conservative design, proportionately larger and therefore better suited to fluidized-bed conversion.

As these examples illustrate, retrofit is very plant-specific. In turn, this suggests that only a portion of coal-fired boilers can be modified with fluidized beds at reasonable capital cost. The greater promise for this option is as an alternative furnace-boiler design in new coal-fired power plants or as a replacement boiler to repower existing steam turbines.

Options in time

From the modification of the coal combustion process itself to the removal of





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he Costs of Control Strategies

'ous strategies have the potential for controlling
emissions from existing fossil-fuel-fired power
ants. Governed by different assumptions, the three
rategies shown here call for different emphasis on
fferent technologies to remove about 10 million
ns of emissions annually—a total much under dis-
ussion today. In each case, the option at the left
elds the greatest reduction of emissions per dollar
ent, and the progressively steeper ramp portrays
e cumulative annual performance and cost of other
tions.

The graph in back represents possible control
sponses assumed in the context of several recent
ngressional proposals. Annual performance and
st increments for each option have been estimated
r the aggregate capacity (megawatts) of power
ants likely to use that option. The combination of
oposed federal law and present state laws and
onomic policies tends to discourage lower-cost
tions and encourage flue gas desulfurization.
e total cost could be more than $12 billion a year.

A more flexible approach, shown in the middle
aph, would use the most cost-effective options to
e fullest possible extent before more expensive
tions were called into play. Cleaning coal of all
ds would not reduce the emission rate to the same
lue at every plant, and increased switching to low-
lfur coal could have awkward implications for the
onomies of high-sulfur coal mining areas; but the
tal technology cost for this strategy is somewhat
ss, at about $11 billion a year.

The more varied mix of options in the front graph
uld be a possibility perhaps four or five years from
w. Predicated on utility industry and federal R&D,
es heavily on new technology—in this example,
e-injected limestone and fluidized beds in ret-
tted boilers, which together reduce overall emis-
ns by as much as flue gas desulfurization can
day. The greater cost-effectiveness of the two new
tions reduces the overall cost of this strategy to
rhaps $9 billion a year.

ility Emission Trends

ntrols imposed on new power plants, beginning in
early 1970s, have yielded significant reductions in
, emissions at a cost of about $6 billion a year.
ese emissions are continuing a decline and by the
ar 2000 are expected to be only about a third of what
y would have been without controls. Proposed legis-
ion to extend control measures to the rest of the na-
n's existing fossil-fuel-fired plants could decrease
, further, but at a likely cost of $12 billion a year. In
years, the next generation of coal plants, based on
erently cleaner technologies, such as fluidized-bed
nbustion and gasification–combined cycle, will offer
emission reductions than achievable by retrofit-
day's plants.

SO_2 and NO_x from the flue gas, the possibilities for retrofit emissions control span a variety of alternatives. Depending on the degree and urgency of what is decided for acid rain cleanup, the nation's pre-1971 coal-fired power plants will be subject to quite different combinations of corrective action, even including the outright retirement of plants that do not justify retrofit.

If, for example, the nation's decision makers choose to deal with the problem by electing an arbitrary and rapid reduction in SO_2 emissions of 10 million tons per year (as proposed by legislation), the control options become effectively limited to those currently available: plant retirements, low-sulfur-coal blending, coal cleaning, and flue gas scrubbers. This approach would involve plants totaling about 200,000 MW of capacity. Making allowance for many kinds of uncertainty, it might cost $11–$15 billion a year to execute, even if various institutional and contractual limitations can be resolved. The large out-of-pocket costs imposed by this approach are primarily due to heavy reliance on scrubbers for more than half of this capacity.

Alternatively, strategies that allow for more gradual reductions in emissions would both open the range of retrofit control options and encourage the use of those that cost least—particularly retirements, blending, and cleaning. Retrofit options under development, such as limestone injection and low-NO_x burners, may provide somewhat more cost-effective control but are probably limited in application and therefore have less potential for emission reduction.

Both of these scenarios offer something of a Band-Aid solution, and an expensive one at that. Besides the tremendous capital costs of add-on equipment or internal plant modification, most of the options incur additional penalties in efficiency and/or reliability.

A still longer-term view would include the approach of preserving capital to speed the development and transition to new coal generation systems that are inherently clean and more energy-efficient than current plants. New systems, such as fluidized-bed and gasification–combined-cycle plants, represent the concept that the use of coal for power generation is not fundamentally in conflict with a clean environment, and thus they have strong appeal as an ultimate solution. The potential for these new types of generation is great enough to introduce another trade-off consideration for decision makers: although they are at least several years from commercial readiness, they allow emission reductions to follow naturally from the current economic and environmental evolution of coal-fired plants. This would eliminate costly Band-Aid approaches that serve to freeze technology in today's plants and would, in the long run, provide improved emissions control in a more cost-effective manner.

The actual steps that the utility industry takes toward emissions control, and when and how they come about, will flow from R&D success and from the form of policy regulation that may be adopted. Whatever the future holds, the industry has a wealth of research results to apply to the acid rain problem. A successful solution will involve continued research and judicious choices among the answers now at hand and within reach. ◻

Further reading

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This article was written by Ralph Whitaker. Technical background information was provided by Kurt Yeager, Callixtus Aulisio, Robert Carr, Stuart Dalton, Michael McElroy, Thomas Morasky, George Preston, Richard Rhudy, and Robert Row, Coal Combustion Systems Division.

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MITIGATING ACID RAIN WITH TECHNOLOGY: AVOIDING THE SCRUBBING-SWITCHING DILEMMA

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June 27, 1983

MITIGATING ACID RAIN WITH TECHNOLOGY: AVOIDING THE SCRUBBING-SWITCHING DILEMMA*

I. INTRODUCTION

In discussing strategies to mitigate acid rain, the debate has generally revolved around two alternatives for reducing sulfur dioxide (SO2) and nitrogen oxide (NOx) emissions: (1) fuel switching facilities to lower sulfur coal, and (2) installing flue gas desulfurization (FGD) units on power plants. These alternatives present a dilemma for Congress between the capital intensiveness of FGD which can translate into higher costs to consumers (at least in the short-term); and, the coal industry effects of massive switching of facilities to low-sulfur coal, which would result in miner unemployment in high-sulfur coal regions.

This paradox regarding acid rain abatement is partially the result of a narrow view of potentially available technologies for controlling SO2 and NOx emissions from stationary sources. Technologies are available now or will be in a very few years which can significantly reduce SO2 and/or NOx emissions without significantly reducing the efficiency of a plant or creating dislocatio in the coal market. These technologies range from incremental combustion modifications for reducing NOx emissions to advanced combustion designs for efficient and clean burning of high-sulfur coal. Proper incentives could accelerate the use of these acid rain mitigating technologies.

The purpose of this paper is two-fold: first, to provide an overview to the accompanying articles on the advancement of SO2 and NOx control technol and secondly, to discuss factors and incentives for influencing their widespread commercial use in conjunction with an acid rain mitigation program. In this vein, a considerable amount of generalization must be done. Readers interested in the specifics of any one process are urge to seek out the articles contained within on those technologies. This overview attempts to give the reader a feel for the current situation regarding SO2 and NOx technologies and therefore should be considered illustrative of current efforts, not comprehensive.

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*The authors would like to acknowledge the research contribution of Mr. Jim Bourne, contractor, in the preparation of this summary.

The paper is divided into five parts: (1) background on the categories of technologies currently available or anticipated in the future, (2) examples of the current research activity in the area and cost estimates for various technologies, (3) identification of factors affecting the introduction of technologies on a commerical scale, (4) analysis of various incentives and strategies for accelerating the introduction of selected technologies as a part of a proposed acid rain mitigation program, and (5) a conclusion.

?I. BACKGROUND

Control of SO2 and NOx emissions can be done either before, during, or after combustion. Pre-combustion strategies include cleaning the fuel before combustion or using low-sulfur fuel. Combustion controls include modifications to the burners or the addition of a reagent to react with targeted pollutants. Post-combustion processes, the most commonly employed pollution control method, currently consist of some form of flue gas desulfurization (FGD) which reduce SO2 emissions after fuel combustion. Finally, advanced systems are currently under development that burn fossil fuels differently than conventional processes, emitting lower levels of SO2 and NOx.

Pre-Combustion Controls

Sulfur oxide emissions result from the sulfur content of the fuel, while NOx emissions occur both from the nitrogen in the fuel ("fuel-NOx") and from the high temperatures in the combustion chamber ("thermal NOx"). The sulfur in the coal is found in two forms: inorganically bound often with iron as pyrites, and organically bound. Although the latter is difficult to remove, the inorganically bound sulfur can be removed by physical means such as crushing and washing.

Physical coal cleaning is a proven pre-combustion control technology. Coal has a lower specific gravity (usually 1.3-1.75) than the impurities associated with coal (such as sulfur) which generally have a specific gravity greater than two. Hence, placing the coal in a solution with a specific gravity between the two causes the coal to float and the impurities to sink. The coal is then removed and dried. Various physical processes are described in Table 1.

Table 1: Characteristics of major wet-coal cleaning devices

Device	Medium	Principle of separation	Sizes typically handled	Unit capacities	Specific gravity range	Cleaning efficiency	Comments
Coarse coal jig	Water	Stratification	6 × ¼ in.	High	1.60-1.90	Good	Typically used to clean coarse coal at relatively high specific gravities. Efficiency decreases rapidly at sizes below ¼ in.
Fine coal jig	Water	Stratification	½ in. × 28M	High	1.60-1.90	Good	Reported to be as efficient as concentrating tables when handling compatible size. High unit capacity.
Hydrocyclone	Water	Centrifugal forces in ascending vortex	½ in. × 100M	High	1.60-1.90	Poor	Poor cleaning efficiency, but can be used as 'scalpers' ahead of more efficient devices.
Concentrating table	Water	Stratification and hindered settling	⅜ in. × 200M	Low	1.50-1.80	Good	Provides good separation when near-gravity material is less than 10% of feed. Requires very low water-to-solids ratio.
Heavy-medium vessel	Fine magnetite in suspension	Float and sink	6 × ¼ in.	High	1.30-1.80	Excellent	Efficiency of separation near theoretical, even when feed contains large amounts of near-gravity material.
Heavy-medium cyclone	Fine magnetite in suspension	Float and sink plus centrifugal forces	½ in. × 28M 1½ in. × 0	High High	1.30-1.80 1.30-1.80	Excellent Very good	Excellent separating efficiency over wide range of specific gravities. Raw feed must be deslimed. Can replace multiple cleaning circuits. Requires no raw-coal desliming.
Flotation	Water	Particle attachment	28M × 0 100M × 0	High Low	N/A N/A	N/A N/A	Not effective for oxidized coal or for removal of pyritic sulfur. More expensive than other cleaning methods.

Source: Coal Cleaning to Improve Boiler Performance. Power, September 1981.

The cleaned coal provides for more efficient burning, reduced fuel transportation costs, and lower sulfur dioxide levels emitted. Although the economics are site-specific, study has shown that often it is economical to clean coal prior to combustion, regardless of any environmental benefits. [1] The major disadvantage of the system involves a relatively low level of sulfur removal. Because the process removes only pyritic sulfur, it generally allows only a 20-35 percent sulfur reduction. Also, there is a tradeoff between increasin sulfur removal and increasing the Btu losses associated with the cleaning process.

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[1] Electric Power Research Institute. Impact of Coal Cleaning on the Cost of New Coal-Fired Power Generation. Report CS-1622. March 1981.

To reduce sulfur further before combustion, development of chemical coal cleaning processes are underway. Unlike physical cleaning, chemical processes also remove organically bound sulfur, in addition to a high percentage of pyritic sulfur. Chemical cleaning is a much more complicated process, requiring chemical reagents to break apart the bound sulfur. Although it is a more expensive process, a higher sulfur removal rate may reduce or eventually eliminate the need for further control modifications, thus making this approach economically feasible.

Combustion Controls and Modifications

Controlling emissions during combustion is a second area where reductions are possible. Combustion control technologies currently under development are often less complicated than post-combustion control techniques, they produce waste products which are disposed of more easily, and the capital and annual costs are, in some cases, projected to be substantially less than current post combustion systems such as FGD and selective catalytic reduction (SCR) for the same reduction capability. For SO2, control generally consists of adding alkaline absorbents, such as limestone, to react with the sulfur-laden gas before the gas exits the combustion chamber. For NOx control, there are a variety of techniques for controlling the supply of air and fuel, along with flame temperatures in the combustion chamber, thus reducing fuel and thermal NOx.

Current research and development of combustion modifications have focused on systems that simultaneously control both SOx and NOx, such as Limestone Injection Multistage Burners (LIMB), and Atmospheric Fluidized Bed Combustion (AFBC). Table 2 summarizes some of the advantages and disadvantages of these two control technologies.

TABLE 2: Characteristics of Selected Simultaneous SOx and NOx Control Techniques

Technique	Current Status	Advantages	Disadvantages	Projected Costs
LIMB	Under development, retrofit operating in West Germany	Easily retrofitable. Inexpensive. 50-70% of SO2 and NOx reductions.	For higher SO2 removal use of another control technique will be necessary.	Capital costs $27-$37/Kw.* Annual costs 5.6-6.1 m/kwh.
AFBC	Commercial facility by late 1980s 2/	Can burn high sulfur coal with good emission control. Dry waste can be disposed of more easily.	Potential problems with bed stabilization at larger sizes. Presence of quick lime in waste may present disposal problem.	Lower costs than current combustion technologies.**

* EPA estimates in 1982 dollars.
** TVA's current projection

Source: Data compiled by CRS.

Of these technologies, LIMB is a particularly promising control process. It has the potential to reduce both SO2 and NOx emissions by 50 to 70 percent, and is designed to be retrofitted to existing facilities. Furthermore, LIMB is projected to be inexpensive to install and operate. The capital costs of LIMB are projected to be between one-seventh and one-tenth that of FGD. 2/

Another combustion system which has received substantial attention, especially from the Tennessee Valley Authority (TVA) is Atmospheric Fluidized Bed Combustion (AFBC). In this process, powdered coal and limestone is injected onto a "fluidized-bed" raised by air pressure from below. Sulfur oxides react with the limestone, while nitrogen oxide formation is reduced due to lower combustion temperatures. Current research suggests that AFBC will provide

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2/ U.S. Environmental Protection Agency. LIMB/LOW NOx Burners - EPA's Program to Develop Low Cost SOx/NOx Controls for Coal-fired Boilers. Revised March 1983.

substantial SOx and NOx reductions at costs less than that for conventional systems. 3/

For control of NOx alone, a number of modifications in combustion techniques have been developed, some of which lead to improved combustion efficiencies. Dual register burners, staged combustion, use of overfire air, reduction of excess air and flue gas recirculation all have potential for reducing NOx emissions. Table 3 summarizes some of the advantages and disadvantages of some of these modifications.

Post-Combustion Controls

Controlling emissions after the combustion phase has been primary emphasis of U.S. SO2 control efforts. Wet scrubbers using lime or limestone are the major means of active SO2 control currently used in the U.S. today, providing over 90 percent SO2 removal capability. This focus on a technological response to SO2 emissions is almost unique among the industrialized countries which tend to favor switching plants to lower-sulfur coals to control emissions. Indeed, when permitted, U.S. utilities have traditionally preferred to fuel switch rather than install FGD units. This reluctance is the result of problems such as plugging, scaling and other troubles that plagued early, first-generation wet-scrubbers; problems which have been somewhat rectified in recent years.

With the Clean Air Act mandating a percentage reduction in SO2 emissions, efforts began to develop a cost-effective dry scrubbing system as an alternative to wet FGD. Dry scrubbing offers some distinct advantages in the control of SO2. Lower energy and less manpower requirements, as well as greater dependability and simplicity may make dry processes more cost effective

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3/ Tennessee Valley Authority. Atmospheric Fluidized Bed Combustion: Technology Development and Demonstration. November 1, 1982.

TABLE 3: Characteristics of Selected Combustion Modifications for NOx Control

Modification	Current Status	Advantages	Disadvantages	Costs
Low excess-air combination	Currently available	Process is more efficient way to burn fuel. Results in 17-38% NOx reductions for all fuel types.		Inexpensive way to reduce NOx levels. Can save money by more efficient fuel burning.
Flue gas recircultion	Currently available	Reduces NOx up to 60% for certain fuels. Also reduced soot levels.	Restricted to low nitrogen fuels since this process reduces thermal NOx only. Decrease of optimum flame temperatures causes lower fuel efficiency.	Installation costs are greater than other low NOx burner systems.
Staged combustion	Currently available	NOx reductions of 30-50%, retrofitable in some cases.	Potential problem with unburned fuel, high level of corrosion and high maintenance requirements.	Low-cost way to reduce NOx emissions.
Dual Register Burners	Currently available	In use since 1972. NOx reductions up to 60% possible using oil or coal.		Capital costs are estimated at $5/kw. Annual operating costs of 0.03 mills/kwh.*

* EPRI estimate in 1980 dollars

Source: Data compiled by CRS.

than wet systems to operate, especially for sources that burn lower sulfur coal and do not need to meet a 90 percent reduction requirement. 4/

The drawback of dry systems include a low SO2 control level and the inability to work effectively on high sulfur coals (more than three percent). Dry scrubbing reduces SO2 emissions by only 70%, versus 90% reductions from wet systems. Also, the cost advantage of the technology versus wet FGD decreases as the sulfur content of the coal increases toward the technology's current three percent maximum. This is because of the quantity of relatively high-cost reagent necessary to react with the sulfur becomes too costly for the process to compete with wet FGD. 5/ Table 4 summarizes the general advantages and disadvantages of wet and dry FGD systems.

A general advantage of post combustion control techniques is that they may be combined with pre-combustion controls, such as coal preparation, to increase the overall reduction of SO2. In particular, the combination of physical coal cleaning and wet or dry scrubbing of only a portion of the flue gas may be economically attractive. Also, the combination can increase the reliability of the control systems. 6/

Post-combustion controls have also been developed for nitrogen oxides. Two such processes include selective catalytic reduction (SCR) and selective non-catalytic reduction (SNR). SCR can provide up to 95 percent NOx control; SNR up to 60-80 percent. SCR uses a catalyst, such as copper oxide, to assist a reaction between SO2 and ammonia (NH3) to form nitrogen

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4/ Satriana, M. (ed.) New Developments in Flue Gas Desulfurization Technology. Noyes Data Corporation, Park Ridge, N.J., 1981. p. 185.

5/ Ibid.

6/ U.S. Department of Interior, U.S. Environmental Protection Agency. Coal Cleaning with Scrubbing for Sulfur Control: An Engineering/Economic Summary. EPA 600/9-77-017, August 1977.

TABLE 4: Characteristics of Wet And Dry FGD Systems

Wet Processes	Energy Requirements	Advantages	Disadvantages	Costs
Lime/Limestone Sodium Carbonate Welman Lord Double Alkali Others	Must reheat flue gases before emissions.	More verstile systems for different coals and sulfur contents. High SOx removal (up to 95%). Some particulate removal. Greatest operating experience.	Large sludge production in some cases. Need to control pH level. Plugging, scaling, and corrosion. Large water requirements.	Require use of more expensive alloys for construction. More manpower needed. Least expensive systems currently in use.
Dry Processes	Require 25-50% less energy than wet systems.	No problems of scaling or plugging. Less manpower needed to operate dry systems. No need to control pH level carefully. Higher availability with simpler system (no sludge control mechanisms) Uses much less water, and of lower quality. Lower maintenance requirements.	Cannot usually use dry systems on coals with sulfur contents above 3%. More expensive reagents required.	Can use carbon steel for vessels. Reagents more expensive than with wet systems. Use less energy-- no reheat of flue gas Less equipment needed since sludge processing not involved. Cost effective ways to reduce SO2.

Source: Data compiled by CRS.

and water. Unfortunately, in some cases, the additional formation of ammonium sulfate and ammonium bisulfate can lead to equipment plugging and clogging. SNR is similar to SCR, except that it does not use a catalyst, but depends on the high temperature of the gases to drive the reaction with ammonia.

Generally, SCR costs about two to three times as much SNR in terms of annualized costs. Both technologies are commercially available with SCR used currently in Japan and SNR on oil refinery preheaters in California. 7/

A final area of work on post-combustion control is simultaneous SOx and NOx control technologies. The goal is to develop single process systems for what is now accomplished with two systems, such as FGD for SO2 and SCR for NOx. As with FGD, there are both wet and dry systems. Wet simultaneous control technologies are currently thought to be economically uncompetitive compared to separate SO2 and NOx control technologies, 8/ although one wet process (Sulf-X) has been reported to be economically attractive. This wet process is regenerative, producing a saleable by-product sulfur. 9/

Dry processes for simultaneous control have been given greater emphasis, due to their potential lower overall costs for NOx and SOx control. 10/ There are several systems available, including the Shell copper oxide process and the carbon absorption process. These control strategies should have high (90% or better) SOx reductions and upwards of 70% NOx removal. Stricter NOx requirements will be necessary before demand for either of

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7/ Parker, Larry B. and Robert E. Trumbule. Opportunities for Increased Control of Nitrogen Oxides Emissions From Stationary Sources: Implications for Mitigating Acid Rain. CRS report 82-217, December 9, 1982.

8/ Dalton, S.M. Current Status of Dry NOx-SOx Emission Control Processes. Presented to 1982 Joint Symposium on Stationary NOx Control. Dallas, Texas November 1-4, 1982

9/ Ellison, William, and Edward Shapiro. The Sulf-X Flue Gas Desulfurization Process. Presented to Tenth Energy Technology Conference and Exposition, Washington D.C. February 28, 1983.

10/ Dalton, S.M. Current Status of Dry NOx-SOx Emission Control Processes.

these systems is great, due to their higher costs in comparison to current systems capable of meeting current emission standards. Table 5 compares the advantages and disadvantages of two of these dry simultaneous control methods.

D. Advanced Technologies

Processes included in this section are more complex than the combustion modification or flue gas treatment processes used currently. Some advanced technologies involve refinements of combustion processes, while others employ revolutionary techniques for the production of energy.

TABLE 5: Characteristics of Two Dry Simultaneous SO2 and NOx Control Technologies

Technique	Current Status	Advantages	Disadvantages	Costs
Copper Oxide	Pilot plant testing in U.S. 40 Mw commercial plant operating in Japan since 1973.	90% SO2 removal 60-70% NOx removal. Low waste by-product level due to regenerative system. No plugging of reactor due to low formation of ammonium sulfates.	High temperatures in process make retrofitting difficult. Process requires about 5% of energy produced from boiler.	High capi and annua operating Capital c $238 per Annual op ting cost 5.6 mills/
Carbon Absorption	Commercial plant now under construction in West Germany (SO2 control only) NOx control still at pilot test level. Prototype testing in U.S. and Japan.	SO2 control as high as 98% 75% NOx reductions. Waste produce reduced by regeneration saleable byproduct produced.	Difficulty in controlling flue gas temperatures. (Increased temperatures reduce SO2 control, but slightly increase NOx control) Sorbent deterioration with use.	Expensive compariso current F systems. Little de unless st NOx emiss required.

* Updated EPA estimate.

Source: Data compiled by CRS.

Another reason for their separate treatment here is due to their state of development. These systems are still several years away from commercial use, but have the potential to burn fossil fuels more efficiently and emit lower levels of SOx and NOx than systems currently in use. These systems generally are not retrofittable, but may be the wave of the future in burning coal in an environmentally-sound manner.

Electron-beam irradiation is one advanced system which is progressing well through developmental stages. Several pilot-plants have operated in the U.S. and Japan, and the producer is now attempting to secure support for a demonstration facility in the U.S. The process involves the dissociation of NOx and SOx by electron beams to form free radicals, and subsequent reactions with ammonia to form ammonium sulfate and ammonium bisulfate. Two process variations are being developed, one with a regenerable by-product and the other with a throwaway system. The process is projected to be approximately 25 percent less expensive than a combined use of wet flue gas scrubbing and selective catalytic reduction to reduce SOx and NOx. 11/

Pressurized fludized bed combustion (PFBC) involves a fluidized-bed burning process, but operates at higher pressures than does atmospheric pressurized fluidized-bed combustion. Since the reaction occurs in a smaller space, the unit is smaller, which may reduce capital and operating costs. PFBC produces less waste than AFBC, and is less sensitive to clogging and plugging of the injection system. PFBC is more efficient, controls NOx better than AFBC and uses less limestone for the reaction with SOx. 12/

11/ Dalton, S.M. Current Status of Dry NOx-SOx Emission Control Process.

12/ National Academy of Sciences. Assessment of Advanced Technology for Direct Combustion of Coal. National Academy of Sciences. Washington, D.C. 1977.

A second emerging technology for converting coal into electricity is the gasification-combined cycle (GCC) power plant. A GCC plant operates by first gasifiying the coal and then burning the resulting clean gas in a combustion turbine at temperatures above 2000 degrees Fahrenheit. The exit gas is transmitted to a heat-recovery steam generator which uses it to power a steam turbine.

GCC is potentially retrofittable, thermally more efficient and most important, is projected to be cost-effective compared with conventional generation systems. A potentially important base load process, GCC is also very flexible in terms of energy output. The system can easily fluctuate outp to meet energy demand. 13/

Combustion of fossil fuels with magnetohydrodynamics (MHD) could virtually eliminate SO2 emissions and substantially reduce NOx emissions. In this process, electricity is generated directly from the thermal energy, bypa the transfer of heat to mechanical energy. An electrically conducting gas is channeled through a duct at high speed in the presence of a magnetic field. This process creates a voltage drop through the stream of gas.

In addition to low pollution emissions, MHD systems are much more energy efficient than conventional processes. While current electric utility plants operate at 33-40 percent efficiencies, MHD systems could operate at efficienci around 50 percent, resulting in significant fuel savings. 14/

13/ Quentin, George. Coupling a Gasifier to a Combined-Cycle Plant. EPRI Journal, April 1981. p. 22-27.

14/ Bienstock, D. and V. M. Maslennikov. Protection of the Biosphere. In Petrick, M. and Shumyatsky, B. Ya. (eds.) Open-Cycle Magnetohydrodynamic Electric Power Generation. A Joint USA/USSR Publication by Argonne National Laboratory, 1978.

III. CURRENT RESEARCH AND COST PROJECTIONS

A. Examples of Current Activity

Research is currently underway involving numerous processes to reduce SO2 and NOx emissions from stationary sources more efficiently and reliably than current systems. A variety of processes are emerging to meet specific emission source characteristics, such as furnace type, fuel type, sulfur content and other variables. These emerging technologies are in various stages of development. Table 6 reviews the availability of some of these technologies.

These technologies are the result of Federal, private and combined federal-private efforts. An example of Federal research is the development of LIMB technology. For several years, the EPA actively supported the development of LIMB technology. It is largely due to EPA that LIMB has advanced to its current state. During the Reagan Administration, however, funds for continued development of LIMB by the EPA have been reduced drastically, as has funding for a demonstration effort. This action has probably lengthened the time required for this technology to reach commercialization.

Another example of Government activity is TVA, who is actively pursuing development of AFBC. TVA has proposed building a 160 mw plant that will burn high sulfur, Illinois coal. The AFBC facility is projected to be on line by 1989, and be less expensive than other conversion technologies. The U. S. Department of Energy has also sponsored pilot plants for various control technologies, including the Wormser grate. The Wormser grate is an industrial-sized fluidized-bed combustion device, of which two commercial facilities have been built. One system provides steam for a meat-packing plant in Amarillo, Texas and the second was retrofitted to a boiler at a university in Massachusetts. The Department of Energy has also agreed to fund the expansion of a Sulf-X demonstration plant which began operations in 1982.

TABLE 6: Current Status of Selected Control Technologies.

	TECHNOLOGY	COMMERCIAL STATUS*
1.	Physical Coal Cleaning	Available
2.	Chemical Coal Cleaning	Under Development
3.	Wet FGD	Various Processes Available
4.	Dry FGD	Various Processes Available
5.	Low NOx Burners	Various Designs Available
6.	Selective Catalytic Reduction	Available (Extensive use in Japan, limited use in U.S.)
7.	Selective Non-Catalytic Reduction	Available
8.	LIMB	Demonstration plant within 3-5 years
9.	MHD	Under development
10.	AFBC	Commercial plant by late 1980s
11.	PFBC	Commercial plant by mid-1990s
12.	GCC	Demonstration plant under construction Commercial plant by 1990s
13.	Electron Beam	Under Development
14.	Carbon Absorption	Pilot plant in U.S. (mid-70s) Demonstration plant in Japan soon
15.	Copper Oxide	Available

* Research is a continuing process with refinements being made and variations on designs being tested. Hence, "available" only implies that a general design is commercially-proven.

Source: Data compiled by CRS.

The Electric Power Research Institute (EPRI) has also been responsible for considerable development of control technologies for utility plants. As the research arm of the utility sector, EPRI has financed numerous research and demonstration projects in order to increase the quantity and quality of control devices. EPRI, along with Bechtel, General Electric, Southern California Edison Co., and Texaco, have pioneered the development of gasification-combined cycle by subsidizing a plant for Southern California Edison, which should start operations in early 1984.

Other examples of industry research and development can be found with the major oil companies. For example, Exxon has developed an SNR device, called thermal DeNOx, for significantly reducing NOx emissions. The system has been developed on oil and gas fired steam boilers and utility boilers, as well as coal fired boilers. Shell Oil has developed the copper oxide process to simultaneously reduce SOx and NOx emissions.

Boiler manufacturers, such as Babcock and Wilcox, Foster and Wheeler, Combustion Engineering, and Riley Stoker are also working on technologies to control emissions, particularly NOx. Examples of their work include development of dual register burners, and Combustion Engineering's Low-NOx Concentric Firing System (LNCFS). 15/

Finally, there are numerous other groups actively researching and refining emission control technologies. The air pollution control industry has become a significant industry in the U.S. with an estimated 111,000 man-years' worth of employment involving fabrication, design, operation,

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15/ Parker, Larry B. and Robert E. Trumbule. Opportunities for Increased Control of Nitrogen Oxides Emissions From Stationary Sources: Implications for Mitigating Acid Rain. CRS Report 82-217 ENR, December 9, 1983.

maintenance and repair, and other jobs. 16/ With the proper incentives, increased private research and development is possible.

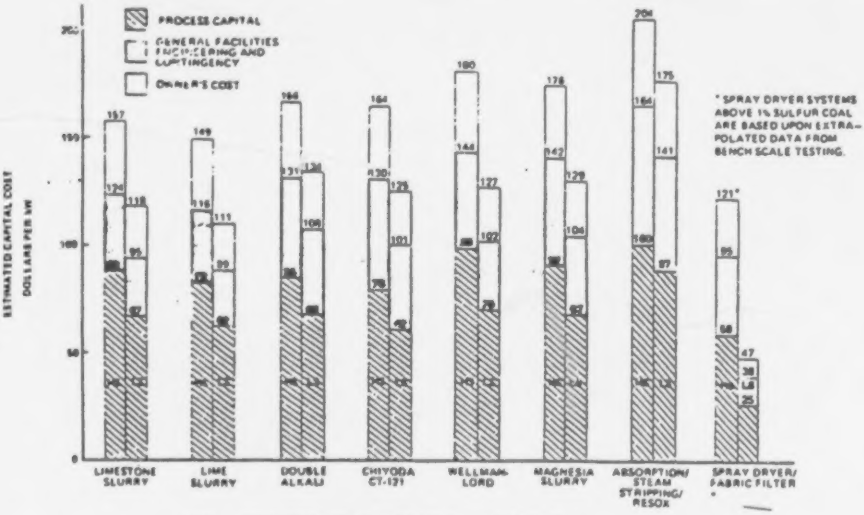
B. Costs

Industries that would be required to reduce emissions of SOx and NOx emissions have voiced their strong concern that reductions would prove very expensive. Industry leaders feel that reductions to lessen the effects of acid precipitation should not be implemented until there is conclusive scientific evidence to affirm a connection between utility and industry emissions and acid rain.

Current standards mandate a percentage reduction in SO2 emissions at new coal burning utility facilities. To meet this standard, wet FGD throwaway systems have been employed widely, and have logged the most operating experience of any system. The capital cost for installing throwaway FGD systems into new facilities adds, on average, about 10% to the cost of construction. The cost to retrofit facilities currently in operation are generally one-third more than for new facilities. Figure 1 presents the estimated cost of various systems in dollars per kilowatt (kw). The first four processes are wet throwaway systems, which have waste disposal problems. Plugging, scaling and corrosion have also affected the performance dependability for these wet systems. The next three systems presented in the figure are regenerative processes. These systems can produce a saleable by-product, or one that is more easily disposable. The reagents used are often recyclable too, which will often reduce operating expenses. The final system, the spray dryer, is a dry process.

16/ H & W Management Science Consultants. Employment in the Air Pollution Control Industry. Prepared for the Industrial Gas Cleaning Institute, February 1982.

FIGURE 1: Flue Gas Desulfurization Estimated Capital Cost



* SPRAY DRYER SYSTEMS ABOVE 1% SULFUR COAL ARE BASED UPON EXTRAPOLATED DATA FROM BENCH SCALE TESTING.

BASIS: NEW 2 x 500 MW COAL FIRED PLANT, MIDWEST LOCATION,
30-YEAR PLANT LIFE; PRICING LEVEL MID-1978 FOR 1980 STARTUP
HIGH SULFUR COAL - 4.0% SULFUR (AVG)
LOW SULFUR COAL - 0.48% SULFUR (AVG)
CAPACITY FACTOR 70%, 6132 HRS/YR
SO_2 EMISSION PER PROPOSED SEPTEMBER, 1978 NSPS

HS = HIGH SULFUR COAL
LS = LOW SULFUR COAL

SOURCE: National Academy of Sciences.

As noted, wet systems have dominated the market for the past decade, and have the most on-line experience. However, due to the problems of dependability and waste disposal experienced by wet scrubbers and despite considerable improvements in their operation, alternatives have been pursued through research and development. While specific cost projections are not available for many of the processes under development, Table 7 presents some representative retrofit costs for some categories of technologies examined in this reader. As indicated, in specific situations, all of the technologies listed could be cost effective in comparison with wet FGD. This is particularly true for LIMB technology which is projected to have capital costs of between 10 and 15 percent that

TABLE 7. Retrofit Control Technologies for a Typical 300 MWe Eastern U.S. Coal Fired Utility Boiler

	Lime/Limestone FGD	Lime Spray Drying	Physical Coal Cleaning	Limestone Injection in Multistage Burners	Low-NOx Burners (NOx Control Only)
Technical Status	Commercial	Early Commercial	Commercial	Developmental	Early Commercial
SO2/NOx Removal Efficiency	90% SO2 Reduction	75% SO2 Reduction	20-30% SO2 Reduction	50-60% SO2 Reduction 50-60% NOx Reduction	60-70% NOx Reduction
Capital Investment ($/kWh)*	260	190	46	27-37	2.0-7.1
Annual Operating Expense (mills/kWh)*	6.4	5.7	1.7	3.1	0.05
Levelized Annual Revenue Requirement (mills/kWh)*	23	18	4.9	5.6-6.1	0.2-0.4

*/ Costs expressed in December 1982 dollars, assuming a remaining boiler life of 15 years and a 40% operating factor.

Source: U.S. EPA

of FGD. This cost advantage for LIMB is enhanced further by factoring in the costs of NOx control not achieved by FGD. However, wet systems probably will continue to dominate the SO2 control market, due to industry's reluctance to use other systems with less operational experience, unless concerted efforts are made to encourage development and demonstration of these potentially more cost-effective technologies.

Significant reductions in NOx emissions, down to .4 or .3 lb. per million Btu, are possible through advanced combustion modifications. The annualized costs of such modifications are estimated in the range of tenths of mills per kilowatt-hour (constant 1980 dollars). If a stricter standard were desired and could not be met by combustion modifications in a timely fashion, then the addition of thermal DeNOx would be the next step. Indeed, thermal DeNOx, in addition to combustion modifications may be able to achieve a .2 lb. per million Btu standard. Such a combination is estimated to cost under 1 mill per kilowatt-hour (annualized cost, constant 1980 dollars). A very strict standard of .1 lb. per million Btu could be achieved either through selective catalytic reduction techniques or combined SOx/NOx reduction techniques. Such equipment would cost in the range of 2 mills per kilowatt-hour, which would be about half the cost of flue gas desulfurization (annualized cost, 1980 dollars.) 17/

For new combustion technologies, costs have been estimated for atmospheric fluidized bed combustion and gasification-combined cycle. As calculated by TVA (see Table 8), both AFBC and GCC have the potential to reduce SOx and

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17/ Parker, Larry B. and Robert E. Trumbule. Lowering NOx Emission Standards for Stationary Sources: Analysis of Current and Future Reduction Potential. CRS unnumbered report, June 21, 1983.

TABLE 8: Cost and Performance Data for Coal-Based Generation Technology

	CONVENTIONAL PULVERIZED COAL			AFBC	GCC	
	SUBCRITICAL 2400 PSI FGD	SUPER-CRITICAL 3500 PSI FGD	LOW HEAT RATE 4500 PSI/ CHIYODA FGD	AFBC	TEXACO 2000°F	TEXACO 2600°F
FIRST COMMERCIAL SERVICE	CURRENT	CURRENT	1992	1993	1991	2000
NET HEAT RATE (BTU/KWH)	9860	9450	8420	9640	9460	8465
NET EFFICIENCY (%)	34.6	36.1	40.6	35.3	36.1	40.3
$/KW (IN SERVICE JANUARY 1981)	995	1000	1105	820	1030	965
LEVELIZED MILLS/KWH (1981-2010)	85	81	78	77	81	79

NOTES: AFBC MEANS ATMOSPHERIC FLUIDIZED BED COMBUSTION.
GCC MEANS GASIFICATION COMBINED CYCLE.
FGD MEANS FLUE GAS DESULFURIZATION.

Source: Tennessee Valley Authority, Division of Energy Demonstrations and Technology (August 1982) and the Electric Power Research Institute 1981 Technical Assessment Guide.

NOx more economically than current systems using FGD. If standards for NOx are strengthen in the future, this cost advantage would increase since both emit NOx at levels below current standards.

IV. FACTORS INFLUENCING INTRODUCTION OF TECHNOLOGIES.

Many of the technologies being discussed here are beyond the initial research and development stages of the commercialization process. The basic research has been done and practical applications have been invented and design As noted, this activity is the result of Federal, private and combined Federal-private research and development efforts. Also, considerable foreign activity has broadened the base of research and development for these technologies.

However, this linkage between public and private research and development activities begins to break down somewhat during the demonstration stage. Fundamental questions regarding the proper extent of Federal research assistance to private industry begin to impede the relationship. These questions have come into sharp focus with the current Adminstration's policy that once the innovation has reached the "proof of concept" stage, it is the business of private industry to determine its marketability and proceed with further demonstration and commercialization activities. The purpose is to allow marketability to dictate the most useful course of innovation, ensuring both usefulness and economy.

Hence, the decision on whether or not to extend incentives to private enterprise to accelerate commercialization of a technology depends on one's assessment of private industry's current and future reaction to the technology. While private industry's commitment to a technology may be largely based on short- or mid-term economics, a government commitment to commercialization need not be. The Government may decide that the long-term economics for a technology are good, or that other social values, such as the environment or national defense, dictate development despite current economics. For example, in calling for incentives for the synthetic fuels industry, the Government used the following language to justify the technology on national security grounds:

> The purpose of this title, and the amendments made by this title, are to utilize to the fullest extent the constitutional powers of the Congress to improve the Nation's balance of payments, reduce the threat of economic disruption from oil supply interruptions and increase the Nation's security by reducing its dependence upon imported oil. 18/

To assist private industry in developing new technology, the Government must either assume some of the risk involved or decide to develop the technology itself. This section discusses four areas of risk that influence commercialization: (1) technical risks, (2) economic risks, (3) regulatory considerations, and (4) institutional considerations.

A. Technical Risks.

For technologies beyond the initial research and development stage, there are two primary technical uncertainties: (1) accelerating development, and (2) potential obsolescence. For these technologies, the technical risk involved is not one of fundamentals, but scale. However, development for new technologies under orderly conditions generally requires about 15 years from the time a small-scale pilot plant is started to the time a commercial plant can begin operation. To compress this time frame involves skipping some development steps or reducing testing time. This procedure increas the risks of setbacks down the road.

A second area of technical risk is potential obsolescence. Technological advancement is a dynamic process with continuing improvements being made on existing and even proposed designs. The decision to commercialize a technology generally prevents any more fundamental design

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18/ P.L. 96-294

changes from occuring, limiting improvements to incremental ones. The severity of the second, third, and subsequent generations of technological problems depends on the expected life of initial technology, the degree of improvement offered by subsequent generations, and the economics involved.

B. Economic Risks.

Any pioneer venture involves economic risks. These economic barriers generally fall into two catagories: (1) barriers to front-end financing, and (2) uncertainty about long-term economic viability. The severity of these problems depends on the specifics of the technology involved and the structure and expertise of the industry installing it. For example, the structure of the utility industry is fundamentally different than the refining industry, being a regulated industry responsible to a State public utility commission and its own stockholders (if investor-owned), as opposed to the refining industry which must answer primarily to its stockholders and to the actions of its competitors in the marketplace. By the same token, the financing of incremental combustion modifications is fundamentally different than building new combustion devices as a utility could possibly fund low-cost combustion modifications through retained earnings, while construction of a new generating facility would require it to enter the bond market to obtain sufficient financing. Any incentives program would have to recognize these differences and be able to respond in a flexible manner.

A major economic barrier to the commercialization of new technologies is uncertainty regarding project feasibility. This uncertainty includes initial cost uncertainty about a particular plant, and the longer term uncertainty about its overall economics compared with alternatives.

Because some of these technologies have yet to be scaled up to commercial sizes, cost estimates are based on estimates and projections, not hard data. When these paper projections are translated into bricks and mortar, the result can make the initial projections appear very conservative.

This question of initial cost uncertainty is related to the second uncertainty regarding long term viability. Just as there is no real life experience in building a commercial size demonstration of some of these technologies, there is no experience in operating one. Questions about reliability, durability, and basic operation and maintainence costs can not be answered until a commercial plant is built. A new design will generally require an extended shakedown period over that of a proven design. Modifications to the design may be necessary. All this can only be projected.

This uncertainty about project feasibility is compounded by another major barrier to commercialization—market uncertainty. The technologies described here provide an environmentally safe way of burning high-sulfur coal as an alternative to low-sulfur coal. However, whether these process are economic vis-a-vis low-sulfur coal depends partially on the dynamics of the coal market. These dynamics include demand for both high- and low-sulfur coal and the cost of transportation, either by rail, barge, or truck, as well as other concerns such as contractual arrangements and taxes. An acid rain program providing no restrictions on facilities switching to low-sulfur coal would put significant pressure on the low-sulfur coal market and their transportation networks. However, how high the market might go is a manner of speculation.

C. Regulatory Problems.

The major potential users of the technologies discussed here, utilities, are a very regulated group, primarily by States. Public utility commissions (PUCs) are enpowered to set "just and reasonable" rates for electricity consumers. This authority can also entail limits on rates of return, mergers, purchases and sale of properties, issuance of securities, construction of facilities, occurence of competitive bids, company performance standards, allocation of power during shortages, billing rules, and promotion of conservation. Several Federal agencies also have some jurisdiction over utility activities: (1) Federal Energy Regulatory Commission (FERC) which regulates rates for wholesale sales and interstate transmission of electricity; (2) Securities and Exchange Commission (SEC) which administers the Public Utility Holding Company Act of 1935 provision regarding SEC approval of mergers; (3) Nuclear Regulatory Commission (NRC) which licenses the construction and operation of nuclear power plants; (4) Environmental Protection Agency (EPA) which sets pollution standards and monitors compliance; and, (5) Department of Energy which enforces the Fuel Use Act and other DOE regulations.

Perhaps the greatest disincentive under this regulatory network is the concept of "used and useful" which underlies regulation by State PUCs. Basically, this concept states that electricity consumers should not pay for new facilities unless they are built and generating electricity. Hence, while construction work in progress (CWIP) is proceeding, an allowance for funds used during construction (AFUDC) is set up by the PUC to provide a return to the utility. But this is only an accounting device; real earnings are not received until the unit enters the rate base.

This situation can present a utility with a cash-flow problem if a significant portion of its earnings are AFUDC. Also, bond rating companies tend to downgrade AFUDC earnings as opposed to cash earnings. Hence, in times of low electricity demand, the inability of utilities to place CWIP directly into the rate base can be a significant deterrent to investment in construction, particularly if the technology involved is capital intensive and requires years to construct. Such a deterrent may be entirely appropriate to prevent utilities from constructing plants which consumers have to pay for, but from which they will receive no benefits for several years. The purpose of identifying this alternative is not to suggest that CWIP should or should not be placed in the rate base in all cases, it is to suggest that selective use of CWIP could provide an incentive for utilities to install some of the control technologies being discussed here.

D. Institutional Considerations.

An underlying constraint in introducing significant innovation in industry is resistance to installing new technology which may affect the reliability of its equipment while not producing any revenues. For utilities, the source of this resistance has its roots partially in the 1970s experience with flue-gas desulfurization (FGD) which was essentially forced on utilities by the EPA. Early installations of this technology had significant reliability problems resulting in forced outages and expensive modifications. It also created a significant sludge disposal problem for utilities. Finally, the FGD unit required use of utility funds to build but provided no new generating capacity and, indeed, reduced capacity at plants by a few percentage points.

Summary

Obviously, the discussion of risk is one of degree. All new development involves risk: accelerated development involves increasing this existing risk even more. Such a situation emphasizes how important the timing of a development process is. In deciding to accelerate development, a decision has been made that the urgency of the problem and the potential benefit of the technology in alleviating it is greater than the increased risk involved.

V. INCENTIVES TO ENCOURAGE USE OF NEW TECHNOLOGIES FOR MITIGATING ACID RAIN

The overall objective of an incentives strategy would be to make new technologies more attractive to utilities and other emitters of SO2 and NOx in controlling these emissions than switching their facilities to low-sulfur coal. Developing such a technology-based acid rain mitigation strategy could consist of two steps: (1) develop the technical and institutional base to make these technologies realistic alternatives to fuel-switching; and, (2) provide sufficient economic and regulatory incentives for utilities and other emitters to choose these technologies over alternatives. The following discusses the effectiveness of selected incentives in removing or alleviating the various barriers discussed.

A. STEP 1: Building the Technical and Institutional Base.

The purpose of Step 1 is to bring technical knowledge and confidence of the new technologies up to the level of current technologies, specifically removing the technical and institutional barriers discussed above. Also, increased technical knowledge would improve the accuracy of cost estimates. This section will discusses three alternatives for achieving this: (1) research, development, and demonstration, (2) information exchanges to improve dissemination of advantages of new technologies, (3) bilateral cooperation with Canada in developing the technologies.

1. Research, Development, and Demonstration. While some of the technologies discussed here are commercially available, there is some uncertainty regarding the scaling up of the other technologies. Hence, some commercial-scale demonstrations would be useful in determining the commercial performance of such technologies under different boiler configurations and operating modes. The expense of such a program depends on the technology:

LIMB and Low NOx burners could be retrofitted to plants volunteered by the utility industry while AFBC would required significant new construction.

The object of the program would be to optimize the performance of such technologies under typical operating conditions. The program could focus only on the most promising designs with an eye toward standardization where appropriate. Such standardization could be important in reducing cost and increasing reliability of such technology.

However, such Federal involvement in research and development may extend beyond the boundaries of the proper Federal role as envisioned by the Reagan Administration. The Administration is currently funding small demonstrations (25MW) of LIMB technologies and retrofits of NOx burners, but has continually called for eliminating the AFBC research program.

2. Information Exchanges. Perhaps just as important as technical demonstrations to commercializing new technologies is user confidence in the technologies. Perceived difficulties, valid or not, in using new technologies can prevent users from choosing a technology regardless of its economic advantages. As noted earlier, there is a well-founded reluctance on the part of industry to some innovations stemming from its experience with first-generation wet scrubbers. Hence, a purposive and expanded program to include utility representatives in the demonstration of technologies, the dissemination of results, and in informal discussions with various interested parties (environmentalists, government, and other industries) could be useful in breaking down distrust.

3. Bilateral Cooperation. Consideration might also be given to conducting technology demonstrations and information exchanges on a bilateral basis with Canada. Canadian utilities and industry are facing many of the same difficulties as their American counterparts. Such demon-

strations could be beneficial to them as well as to ourselves. Such bilateral cooperation in accelerating development of technology has precedent. During World War II, a cooperative effort was established with Canada for the development of synthetic rubber. A similar procedure could be employed for the effort needed to mitigate acid rain.

Besides technical advantages, cooperation may assist in breaking down some growing distrust between the Canadians and the United States over U.S. commitment to reduce interboundary pollution. This distrust has grown to the point where Canadian representatives have publicly accused the Reagan Administration of stalling on acid rain and have begun discussing acid rain mitigation directly with the Congress. A cooperative research, development, and demonstration program leading to SO2 and NOx reduction might help in reducing such tensions.

B. STEP 2: Commercialization Incentives.

The second step of a proposed acid rain mitigation program could be to encourage use of these new technologies over fuel-switching. For the purposes of this study, we have defined three categories of incentives:

> Direct. Direct incentives are designed to improve the economic feasibility of a technology, reduce project risk, or provide easier access to capital for users. Such incentives may focus on either front-end or long-term operating costs, or both.
>
> Indirect. Indirect incentives are designed to make alternatives to new technologies less attractive, thereby making new technologies appear more attractive.
>
> Regulatory. Regulatory incentives mandate the use of a specific technology or achievement of a set of goals only attainable with certain technologies.

Each type of incentive works differently depending on the specific technology, the specific incentive, and the structure of the industry.

For the purposes of this paper, we are primarily interested in direct incentives: incentives which will improve inherent economics, reduce project risks, or provide access to capital. This emphasis is designed to maximize the flexibility of the mitigation strategy and minimize long-term Government involvement. Some incentives will have a secondary indirect effect of discouraging fuel switching. Of the six incentives discussed, four are primarily financial subsidies, and two involve regulatory changes to improve access to capital.

The primary industry highlighted in this discussion will be the heavily regulated utility industry. As a regulated industry, utilities have some unique problems in regard to financing new technology, particularly access to capital. Hence, while most of the financial subsidies discussed here are equally applicable to regulated utilities as well as other unregulated industries emitting SO2 and NOx, the regulatory changes would be only appropriate to the utility industry.

1. Construction Grants. One comprehensive means of commercializing new technologies would be to provide construction grants to assist utilities and other industry in financing these technologies. Such assistance could be partial (sufficient for utilities or industry to choose a specific technology) or total. Such an incentive would have the following beneficial effects:

a. Improve the economic feasibility of the project by funding at least part of the capital costs

b. Reduce project risk by having the government assume some of the financial risk

c. Provide users with a ready source of capital

d. Discourage use of fuel-switching by denying grants for that alternative.

Disadvantages to construction grants depend on how they were funded and administered. One possible means of funding a grant program would be from a user fee on consumers of electricity. For example, analysis indicates that the capital costs of a twelve-year eight million ton reduction of SO2 can be funded through either a phased-in 3-mill user fee on fossil-fired electric generated within the eastern 31 States, or a 1-mill user-fee on all electrici generated or imported into the contiguous 48 States. If new technologies are available to reduce capital costs, a twelve-year, ten million ton reduction can also be funded by these two fee proposals. The average rate increase for a 3-mill fee would be under 4 percent and the increase would be under 2 percer for the 1-mill program. 19/ Such percentage increases would generally be large in the midwest (which has lower than average electricity rates) and lower in New England (which has higher than average electricity rates). Also, the effective percentage would decline over time as other factors drove up the average cost. The fund would have the effect of levelizing the cost of acid rain mitigation geographically to the benefit of midwestern States. New Englan States would, in effect, be assisting the Midwest in cleaning up its own pollu however, the national/international character of the problem could justify such a redistribution. Also, because Midwest residents are more dependent on electricity than New England residents, there would be some extra cost per capita that would be borne by residents of that region.

Besides raising the question of equity, an acid rain "superfund" also raises questions regarding how it would be administered and the duration of the user fee. Answers to these questions would depend on the projected cost of the program, degree of financing the fund was to provide, and the specific technologies funded.

19/ Parker, Larry B. Distributing Acid Rain Mitigation Costs: Analysis of a Three-Mill User Fee on Fossil Fuel Electricity Generation. CRS unnumberec report, April 11, 1983; and, Parker, Larry B. Distributing Acid Rain Mitigatic Costs: Analysis of a One-Mill User Fee on Electricity Generation in the Contig 48 States. CRS unnumbered report, April 22, 1983.

2. Investment Tax Credits. Investment tax credits permit an industry to deduct part of its capital investment from its tax liability, and are employed frequently by the Federal Government to encourage certain investments because of their fairly non-intrusive nature. The advantages of this alternative are:

a. Improves economic feasibility by reducing effective capital costs to industry

b. Reduces project risks by providing benefits in early years

c. Requires no significant active involvement by the Federal Government.

Unlike construction grants, investment tax credits may not be applicable in all cases. First, companies must have a significant tax liability to be offset by the proposed tax credit. This could be a significant constraint for utilities which may not have the tax liability necessary to take advantage of the proposed credits. Second, public utility commissions may force utilities to provide rate relief from the tax credit rather than allow the utility to retain the savings for capital investment, unless the proposal provides for tax normalization. Finally, it should be noted that investment tax credits will reduce the tax revenues of the federal government at a time when the government is running significant deficits.

3. Accelerated Depreciation. A standard method of encouraging new investment in fairly risky ventures is to allow accelerated depreciation of the asset. The advantages are:

a. Reduces project risk by providing revenues in the early years

b. Provides shorter payback period resulting in less operating risk

c. Affects the timing, but not the overall take of the Federal Government.

While accelerated depreciation improves the cash flow of a project, it only secondarily improves the project's overall economics or the developer's access to capital by shortening the payback period of the investment. Also, current law already provides some accelerated depreciation benefits to industry. Whether more advantages would provide any additional incentive is unknown.

4. Pollution Control Bonds. Pollution control bonds are a form of loan gu antee to utilities to build pollution control equipment. Their advantages are:

a. Improves economic feasibility by reducing financing costs

b. Provides easier access to capital.

Currently, pollution control bonds are tax-free because they are issued by a State authority on behalf of a local utility. Because they are issued by the State, they take on the character of a municipal bond and hence save the utility about 300 basis points in financing costs, depending on market conditions. However, it is unclear that a State affected by an acid rain mitigation program could extend its "full faith and credit" to cover the potential costs of such a program without possibly increasing taxes.

The credit of the Federal Government could be employed to secure a new pollution control bond specifically designed for an acid rain program. Such bonds could take one of two forms. The bonds could carry a Federal guarantee but no tax advantages thereby saving a utility at least 100 basis points or more depending on the utility's bond rating and market conditions. Alternatively, the bonds could carry both the Federal guarantee and a tax exempt status. Such a bond would save utilities about 300 basis points depending on market conditions, but would cost the Federal Government tax revenues. Both of these proposals could cost the Federal Government money if a utility defaulted.

5. Permitting CWIP into the Rate Base for Pollution Control Equipment. Placing construction work in progress (CWIP) into the rate base has been a controversal proposal in some states for many years. The advantages are:

a. May provide easier access to capital

b. Depending upon the circumstances, can have a secondary effect of improving economics by reducing financing costs.

The primary obstacle to allowing CWIP into the rate base has been a fear that it would encourage unwise construction. Yet, if the change were restricted to pollution equipment, this fear would be abated. However, permitting CWIP into the rate base, while improving the financial condition of utilities and their access to capital, does not directly reduce the risks of commercializing the technologies being discussed here.

6. Consumer-Risk Schemes. Consumer-risk schemes involve ensuring utilities that the cost of new technologies can be passed on to ratepayers and not absorbed by investors. The advantages are:

a. Reduces project risk to investors by transferring it to ratepayers

b. Provides easier access to capital.

As in the case of permitting CWIP into the rate base, consumer-risk schemes are limited to utilities. Also, by transferring cost to ratepayers, there are fewer checks on costs, depending on the specifics of the scheme and the role of the PUC in monitoring it. Hence, the cost of building pollution control equipment might rise under a consumer-risk scheme.

C. Matching Incentives to Technologies: An Analysis of Selected Technologies

As noted previously, an important aspect of an incentives program is matching the appropriate incentive to a given technology. While the economic aspect of this is very site-specific, some generalizations can be made regarding which of the above incentives appear most effective for encouraging a specific technology. For the purposes of this analysis, five technologies, covering the range of possibilities, are focused on: (1) NOx combustion modifications, (2) physical coal cleaning, (3) LIMB, (4) wet and dry FGD, and (5) AFBC.

Concentrating on the Step II incentives, the impact of each incentive on either the economic feasibility, project risk, or capital availability

TABLE 9: Impact of Incentives on Economic Factors Affecting Commercialization*

	Economic Factor		
INCENTIVE	Economic Feasibility	Project Risk	Access to Capital
1. Construction Grant	1	2	1
2. Accelerated Depreciation	2	1	2
3. Investment Tax Credit	1	2	2
4. Pollution Bonds	2		1
5. CWIP in rate base	2		1
6. Consumer-risk Schemes		1	2

* "1" = primary impact of alternative, "2" = secondary impact of alternative. NOTE: Priorities are relevant only to the individual alternative; no attempt has been made to place priorities across alternatives.

Source: CRS

aspect of financing new technology is summarized in Table 9. As indicated, each alternative has specific qualities in regard to encouraging investment. It should be noted that the primary or secondary impact of one incentive on alleviating an economic constraint may be different than the primary or secondary impact of another incentive, in terms of method, degree and effectiveness. Hence, the same general need of different technologies may require different incentives. This is discussed below by technology.

1. Combustion Modifications. The major difficulty with low NOx combustion modifications is convincing utilities of their reliability. In congressional testimony utilities have expressed concern about blowing

up the boiler, corrosion, erosion, and other types of problems. 20/ These concerns must be overcome for widespread commercialization to occur. This can be done by either Step 1 alternatives (particularly demonstrations and information exchanges), or by administrative or regulatory action, if the concerns are determined to be unfounded.

Low NOx combustion modifications represent the most incremental and lowest cost alternative of the technologies being discussed. Cost for retrofitting such equipment on utility boilers range from $0.5 to $5.8 per kilowatt, depending on the specific modification. 21/ For example, to retrofit a 500 megawatt plant with dual register burners providing between 40 and 50 percent removal would cost about $1.25 million. Such an amount could probably be funded through retained earnings, avoiding the need to obtain financing. However, if a utility was required to retrofit several of its plants with such burners, the cost might be sufficient for the utility to require some financing. In this case, a pollution control bond might provide sufficient access to the captial market to install the equipment. Of the other alternatives influencing access to the capital market, the short construction schedule of installing NOx control equipment would tend to negate much of their advantages while construction grants might be considered overkill, given the modest capital costs.

20/ U.S. Senate. Committee on Environment and Public Works. Technical Inquiry on Acid Rain. June 2 and 3, 1982.

21/ Electric Power Research Institute. NOx Regulatory Changes and the Electric Utility. A Guidance Manual for Air Quality Modeling in Planning, Siting, and Emissions Control. September 1981.

2. Physical Coal Cleaning. Coal washing is unique in two respects. First, the technology is proven at commercial scale, and no significant technical questions exist. Second, it is a technology which would be installed primarily by unregulated coal companies, not utilities. For the former reason, a coal washing strategy could be introduced faster than the other altenatives being discussed, indeed, almost immediately. It is generally considered a cost-effective alternative when all of the advantages (such as improved boiler performance and lower transportation costs) are included.

For coal washing, a major consideration is the size of the coal company seeking assistance. Most coal washing facilities tend to be on the large size, around 14,000 tons per day input or more. Such a facility is estimated to cost about $30 million and will clean enough coal for a 1,000 megawatt plant. Presumably, smaller facilities could be made for small mine producers who dig nowhere near the 3 million tons per year the above facility could handle, if they have the coal reserves to justify such a long-term investment. Because small mines tend to be somewhat marginal, significant incentives in the form of a construction grant may be necessary to induce purchase.

For larger firms or utilities, the financing problem would not be as major, the concern being project risk and access to capital. Alternatives such as income tax credits (if the utility has sufficient tax liability) or permitting CWIP into the rate base might be sufficient. In more extreme situations, a pollution control bond might be appropriate.

3. Limestone Injection Multi-stage Burners. The major barrier to LIMB is technical: no commercial size boiler has been retrofitted with the technology. Hence, a program to demonstrate this technology on a

commercial scale is of paramount importance. It is also a potential research area in which to include Canada, since Ontario and some of the maritime provinces burn fairly high-sulfur coal (some bought from Pennsylvania and West Virginia) and they also need to develop a way of burning it cleaner.

At an estimated cost of $40 per kilowatt installed, LIMB is projected to be very competitive with low-sulfur coal, given current differentials. However, the cost is sufficient perhaps to require some assistance to utilities for financing and to overcome their reluctance to install a relatively unproven technology. Depending on the financial state of the utility, a pollution bond or even a grant might be necessary to draw utilities from a more proven technology.

4. Flue Gas Desulfurization (Wet and Dry). Unlike some of the other retrofittable technologies discussed here, FGD generally does not have a cost advantage over switching to low-sulfur coal. However, FGD is a proven technology. Excluding site-specific technical difficulties in some cases, the major constraint on use of FGD is economic feasibility. A construction grant would be the most direct method of improving such economic considerations. However, given the general high cost of FGD compared with the other alternatives being discussed here, administrators of the grant program might want to encourage FGD only as a last resort.

5. Atmospheric Fluidized Bed Combustion. Unlike the other technologies discussed, AFBC is not currently designed as a retrofittable technology. Instead, significant rebuilding of an existing plant site would be necessary to install AFBC. Combined with its current stage of development, AFBC represents the alternative with the most uncertainty, and therefore, the technology in need of the greatest assistance.

Implementation of Step I alternatives is the first prerequisite to commercializing AFBC. As noted earlier, some significant demonstration work is currently underway. Such effort might consider the possiblities of refurbishing an existing site with AFBC: if the costs can be kept under 50 percent of the initial price, then the AFBC plant would avoid being reclassified as a new source under the Clean Air Act; if not, a waiver could be provided.

For commercializing the technology, a consumer-risk scheme might be appropriate along with a partial construction grant depending on the financial strength of the utility. If the technology proves very economic, permiting CWIP into the rate base along with a pollution control bond might be sufficient to encourage use.

D. Developing an Acid Rain Incentives Program: Other Considerations

While research and financial incentives can provide a basis of an implementation strategy, an overall acid rain mitigation program would require a regulatory context in which to function. The overall reduction would have to be mandated, along with a distribution strategy. Some alternatives may require regulatory assistance. For example, coal washing may require a regulatory requirement to ensure coal operators of a market for their cleaner, but more expensive coal. The Government may wish to discourage fuel-switching through various regulatory devices.

Hence, a comprehensive acid rain incentives program presents some significant questions regarding the relationship the Federal Government should take vis-a-vis the various inequalities that would arise under an acid rain program. While major discussion of these questions are beyond the scope of this paper, some of them are identified below.

a. How involved does the Federal Government want to get in order to alleviate the various inequalities (regional and economic) that will occur if economic forces are left alone to choose acid rain mitigation controls?

b. What relationship would a Federal incentives program have with State PUCs which regulate utilities?

c. What sort of balance does the government want to strike between incentives and regulation?

d. What criteria should the government use in assessing industry's requests for assistance?

Clearly, these are but a representative sample of the questions the Congress and the administrating agency might want to consider in designing a comprehensive incentives program for mitigating acid rain.

VI. CONCLUSION

In avoiding the scrubbing-switching dilemma, the analysis above suggests that much of the problem with new technology may be real and preceived technical difficulties. These technical difficulties result in economic difficulties, particularly in terms of access to capital. (See Table 10)

For many of the technologies discussed in this reader, the real technical difficulties involved are not insurmountable. Indeed, many of them could be resolved and commercial-size demonstrations developed within ten years, if effort is focused on that objective.

TABLE 10: Barriers to Development of Selected Technologies*

	Commercialization Factor			
TECHNOLOGY	Technical/ Institutional**	Economic Feasbility	Project Risk	Access to Capital
NOx Combustion Modifications	1			2
Physical Coal Cleaning			2	1
Limestone Injection Multistage Burners	1			2
Flue-Gas Desulfurization		1		2
Atmospheric Fluidized Bed Combustion	1			2

* "1" = primary problem, "2" secondary problem. NOTE: Priorities are relevant only to the individual technologies; no attempt has been made to place priorities across alternatives.

** Includes both real and preceived technical difficulties.

Source: CRS

The economic incentives discussed here are not radical, all of them have been used in various ways in the past. Depending on the overall objectives of the incentives program, they do not necessarily have to involve major government expenditures. Indeed, if the country decides to levelize the cost of implementing the program through a user fee, then no direct expenditures from the treasury may be necessary. 22/

In the final analysis, the overriding factor in developing an acid rain incentives program is the need for a concerted effort by the Government to achieve necessary reductions through new technologies. The technologies either exist now or will in the next few years. Most of the technologies are projected to be more than economically competitive with current technology. The basic decision that has to be made is whether the acid rain problem is serious enough to warrant the effort.

22/ For examples of this alternative, see Parker, Larry B. Distributing Acid Rain Mitigation Costs: Analysis of a Three-Mill User Fee on Fossil Fuel Electricity Generation. CRS unnumbered report. April 11, 1983; and, Parker, Larry B. Distributing Acid Rain Mitigation Costs: Analysis of a One-Mill User Fee on Electricity Generation in the Contiguous 48 States. CRS unnumbered report. April 22, 1983

Ex
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DEUTCH REPORT

REPORT OF THE
[redacted]

(Report of the Ad Hoc Committee to Review the National Acid Precipitation Assessment Program)

John Deutch, Ch.

United States Environmental Protection Agency
Science Advisory Board
Washington, D.C. 20460

December 1983

Excerpted from "D. General Findings on the Present NAPAP Efforts."

(6) Control technology is a central component of the acid deposition problem and is currently not included in the NAPAP program. The Federal funding level for development and demonstration of new control technology should be increased substantially to complement on-going industry commitments. The development of new and improved, retrofitable, emission control technologies followed by successful pilot- and demonstration-scale testing, is of key importance in the potential long-term mitigation of acid deposition.

A number of improved control technologies to reduce source emissions are under development at various scales of operation. All have incremental associated capital and operating costs which must be compared to the present scales of development and accumulated operating experience. The urgent need for a technically sound basis to evaluate the benefits and costs of these control options and tightened regulations requires an accelerated national program of development and demonstration over at least the next five years.

These developmental processes include (a) physical and chemical coal beneficiation (cleaning) prior to use, (b) combined SO_2 and NO_x removal, either though furnace sorbent injection (limestone, dolomite, etc.) in conjunction with staged combustion or though development of improved flue gas cleanup (scrubbing) processes, (c) modification of pulverized coal furnaces to fluidized bed combustion having much lower SO_2 and NO_x emission characteristics, and (d) intensive coal cleanup through conversion to clean synthetic petroleum or solid fuels. In addition, increased research emphasis should also be placed on the impacts of these retrofitable processes on water quality, and the quantity and the quality of solid waste produced.

Because control technology is integrally related to combustion system design and because of the magnitude of the required R&D effort, the Review Committee recommends that the federal focus for this national program be the DOE and that it be planned and implemented in conjunction with the private sector. EPA should maintain its current support role in technology development, thus avoiding conflict of interest while maintaining a strong information base for regulatory decision making.

A major Federal program (several tens of millions of dollars per year) for development and demonstration is needed in addition to basic research support for longer-term fundamental studies. These studies include the general areas of coal clean up, combustion control, post-combustion monitoring, effluent identification, and novel techniques for cleanup.

Both furnace sorbent injection and fluidized bed conversion are two promising process developments which particularly require expanded development and demonstration efforts. This will resolve remaining engineering uncertainties and will provide confidence on commercial application to both new and existing combustion sources by the end of this decade.

The importance of this expanded emission control development and demonstration program is underscored by the fact that approximately 40% of the total cost of a coal-fired power plant today is related to environmental control. The results of the proposed program will support accelerated resolution of this perceived conflict between coal and the environment, while avoiding unnecessarily expensive and inefficient solutions which freeze control technologies in today's plants.

Senator DOMENICI. I have no questions at this point, but I'm going to yield to the Senator here. I would just make an observation and perhaps you could comment.

Do I understand then that Senate bill 1925, as suggested by the distinguished Senator from West Virginia, that that proposal, while it doesn't directly address the issue of acid rain, is intended by the sponsor, by the principal sponsor to focus for attention by way of research and development money in the Department of Energy on that issue?

Senator BYRD. Yes, Mr. Chairman, but it goes beyond that. But I think that the acid rain debate certainly should serve as a stimulus to favorable action on this legislation.

That debate, I think, focuses upon the switching versus scrubbing processes that are presently available. And as I have indicated in my prepared statement, to pursue either of these would be a great cost. Switching would be a great cost to the high sulfur areas of West Virginia and other States, and to people who work in those industries, the high sulfur mines.

The scrubbing process, to utilize that to bring down the sulfur dioxide and nitrogen oxide emissions by 8 million tons would create massive capital expenditures that would be necessary. And as I have indicated in my prepared statement, in West Virginia alone, five of the powerplants would require scrubbers, and this would be at a cost of over $1 billion to those five powerplants.

So I think the attention is being drawn to the acid rain problem. We don't really have the answer to that. The scientific community has not reached a concensus as to the origins, the causes and effects of acid rain. And I would hope we would go a bit slower and not take action which might prove to futile and very costly in terms of capital expenditures and jobs until we have a better concensus within the scientific community as to the origins, the causes and the results.

In the meantime, the processes that would be promoted by the enactment of this legislation would increase the use of coal and would develop new, and advanced technologies with reference to the combustion of coal, precombustion, during combustion, postcombustion of coal.

So it would increase the use of coal. I think it would enhance our national security, and would promote jobs in the coal industry, and promote the combustion of coal in an environmentally sound manner.

Senator DOMENICI. I thank the Senator.

Senator Ford.

Senator FORD. Thank you, Mr. Chairman.

I have one or two questions of Senator Byrd.

Senator Byrd, in a couple of places in your bill, it refers to, "coal of all ranks," end of quote.

Am I correct in assuming that your legislation includes research and development on low-sulfur coal as well as high-sulfur coal, of coal mined in the West, of coal mined in the East as well?

Senator BYRD. Yes, Senator Ford. Your observation is a correct one. The use of all coal is what we strive for.

There are those in the low sulfur-producing communities that feel the acid rain programs that would be mandated by pending legislation would benefit their areas, but they forget that a chain is as strong as its weakest link.

And as I have attempted to discuss this with them, I suggested that the low-sulfur coal people, they'll be next. That the overall objective would be to stop the burning of all coal, not just high-sulfur coal, but low-sulfur coal.

And to the arguments of those low-sulfur interests in southern West Virginia, to the effect that its legislation to deal with acid rain before we stop, look and listen, will result in enhanced employment opportunities in their areas and the coal miners will have lost jobs in the high-sulfur area.

My answer is, you had better get together with those high-sulfur people because sooner or later it's going to be you. When this legislation passes and closes down the high-sulfur coal mines in northern West Virginia, you won't even be able to employ the miners who lose their jobs in those areas because you're going to reemploy those miners in your own areas who have become unemployed. And what about the baker, the butcher, and the candlestick maker? You are going to see ghost towns in areas like northern West Virginia.

So I say to these people, don't think for a moment that you're going to escape. The high-sulfur people will go first, and then you will be next, because the ultimate objective is to stop the burning of coal, which I have indicated has sulfur and nitrogen oxide. All coal, all sulfur coal has these ingredients as well.

So yes, the objective here is to use all coals, high-and-low sulfur coals, and western coals and coals in Appalachia, Kentucky, and West Virginia.

Senator FORD. Senator, you and the chairman got into a little bit of the acid rain problem, but I have the impression from your statement that you're saying that the acid rain issue is not the sole motivating factor for the development of your legislation. I think you're saying that the acid rain debate highlights in a very dramatic way the need to develop new technologies. Is that an accurate interpretation?

Senator BYRD. The Senator accurately interprets my statement and the objective of the legislation.

As I have pointed out, Federal R&D efforts with respect to coal technologies have declined in the past 3 years in particular. And so this legislation, of which you are a cosponsor, and I thank you, Senator Ford, is an effort to reverse that trend.

It is a statement that this is what the Congress expects to see happen in the area of coal R&D. We want the Department of Energy to address the need for more economically attractive coal technologies.

The acid rain debate, as you have correctly observed, has a broader sense of urgency to this situation. There are a number of proposals which allegedly would produce acid—would reduce acid deposition in coal-fired powerplant emissions. And these proposals put the issue in perspective for us.

When you look at the alternative ways of controlling powerplant emissions, you find that all we've got at the present time, even though there are new and advanced processes, the things that are actually applicable at this point, it seems, deal with the scrubber or switching dilemma. And we ought not be in that position as far as coal technology is concerned. There are new and advanced technologies which are economically and technically more attractive than scrubbers and switching. And this bill would let us get started working on these.

Senator **Ford**. One other quick question. You don't expect your legislation to replace the current R&D program at the Department of Energy, do you?

Senator **Byrd**. No, Senator Ford. This legislation would provide for programs that would build upon and complement the programs that are presently envisioned by the DOE, they would not substitute for those.

Senator **Ford**. What role do you see industry playing in the development of coal technology under your bill? Would the industry be expected to participate in the identification of technologies and projects which would be pursued? Would industry be expected to make a significant contribution and sharing the cost of engineering the development projects?

Senator **Byrd**. Yes, Senator Ford.

Industry cannot afford the costs of development these new and advanced technologies alone. The coal industry has been a boom-and-bust industry. It's had its ups and downs, mostly downs, since the very beginning. And industry simply cannot afford the cost along, as I have indicated, of pursuing these very costly new, and highly advanced technologies, and so this legislation would encourage and promote cooperation and the coordination of effort among the Federal Government, the universities of the country, industry, the private sector, and so on.

I think that the Federal Government has the responsibility to do this, not only from the standpoint of helping the economy and reducing our very adverse trade balance, but also from the standpoint of national security, for which the Federal Government bears the greatest responsibility.

Senator **Ford**. I thank the distinguished Senator.

Mr. Chairman, I have no further questions.

Senator **Domenici**. Senator Melcher.

Senator **Melcher**. Thank you, Mr. Chairman.

I want to commend the Democratic leader. There hasn't been anyone during the past 20 years who has been as solidly and consistently in the forefront of the coal industry for both the companies and the workers in that great industry of ours.

Coal, after all, is the strongest suit we have in energy in the United States, and what's lagging is the research and development for new processes and better utilization of that coal.

Our Democratic leader has described his bill, which is an excellent bill. He has again taken the lead in providing the Senate the opportunity to enact good, solid legislation to move coal and the entire energy policy forward for the United States.

I find much to commend Mr. Leader, in your statement. Particularly, I note that you have emphasized correctly the lack of research and development for new coal technologies. I thank you for that. I assure you I will do my utmost to work with you for those accomplishments.

Senator **Byrd**. I thank you, Senator Melcher, for your comments and for your support.

Senator **Domenici**. Senator, thank you very much for your observations.

We have a distinguished guest. Senator Stennis, do you desire to inquire of the distinguished Democrat leader?

STATEMENT OF HON. JOHN C. STENNIS, A U.S. SENATOR FROM THE STATE OF MISSISSIPPI

Senator **Stennis**. I'm here primarily today supporting Senator Melcher's bill. I don't know whether you have gone into it or not, I just came in. And we have a small fragment of some of this magnetohydrodynamics research going on by an outstanding professor down at Mississippi State University. I went in there just to say hello to him with the president and stayed an hour; you know, his explaining how he was getting into this thing and how important it was, and I have been an ardent supporter of it ever since.

So I'm glad to be here and thank you for recognizing me.

[The prepared statement of Senator Stennis follows:]

April 9, 1984

John C Stennis

STATEMENT OF SENATOR JOHN C. STENNIS
TO THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
ON THE
MAGNETOHYDRODYNAMICS RESEARCH DEVELOPMENT AND DEMONSTRATION POLICY ACT OF 1983

Mr. CHAIRMAN:

I deeply appreciate the opportunity to be here today and I am also grateful to you, Mr. Chairman, for holding these hearings on the Magnetohydrodynamics Research Development and Demonstration Policy Act of 1983, which I have the pleasure of cosponsoring.

Coal is very important to our nation's economy and national security. MHD offers an important technological advance for converting coal into clean, economic electrical power in a very efficient manner.

MHD was first demonstrated in this country and is now being worked on by industrial firms, research and development organizations, electric utility companies and colleges and universities, including Mississippi State University, which has a growing reputation in MHD diagnostics.

S. 1278 is a good bill, Mr. Chairman. It calls for a comprehensive development plan and sets a time frame within which to complete the development of MHD. It also calls for a cooperative development effort between the Department of Energy and the private sector, and makes provisions for international cooperation.

I am pleased that the Department has already started discussions with the private sector on a joint MHD program. I believe the passage of this bill will provide the necessary legislative authority for this industry/government initiative, while again demonstrating congressional support for a positive national MHD program and coal technology development in general.

Senator DOMENICI. Now we're going to have two panels. We're going to have an administration representative, and then two panels.

William Vaughan, Assistant Secretary for Fossil Energy, the U.S. Department of Energy, will now testify, then Carl Bagge and the panel No. 1.

Mr. Secretary, we're glad to have you here. We have your detailed statement. It will be made a part of the record. You may proceed as you desire.

STATEMENT OF WILLIAM A. VAUGHAN, ASSISTANT SECRETARY, FOSSIL ENERGY, DEPARTMENT OF ENERGY; ACCOMPANIED BY DONALD BAUER, OFFICE OF FOSSIL ENERGY

Mr. VAUGHAN. Thank you very much, Mr. Chairman, and members of the subcommittee.

With your permission, I am submitting my formal statement for the record, and I would like at this moment to summarize the Department of Energy's comments on the two legislative proposals being considered this morning.

With me at the table is Mr. Donald Bauer, my principal deputy in the Office of Fossil Energy, and Don will assist me in answering your more detailed questions.

Mr. Chairman, as has been stated, both S. 1925 and S. 1278 are intended to help foster the Nation's technological capability to use coal, our most abundant fuel resource.

The originators of these bills, and indeed this committee as a whole, have long been avid supporters of increasing the contribution that coal can make to our Nation's energy future.

In this regard, their goals are consistent with those of the Department of Energy and the administration. And I heartily endorse the concept or the target of these bills.

Our Research and Development Program, as proposed by the administration's fiscal 1985 budget, has been fashioned from the basic principles established by the 1983 National Energy Policy Plan.

Specifically, the coal program is oriented primarily toward achieving one of two strategies outlined in that policy plan; to promote a balanced and mixed energy resource system.

To do this, we have placed a high priority on improving the competitiveness of coal in markets currently dominated by oil and gas.

In accordance with this objective, the President's fiscal 1985 budget request reflects a commitment to establish a stable and productive Federal funding level for the coal program.

Our 1985 coal budget of $178 million represents a 75-percent increase over the fiscal 1984 request. Although this amount is less than the level appropriated last year, it represents a major step towards compromise with the Congress on this vital issue.

Let me turn to those two specific legislative proposals. On pages 3 and 4 of my formal statement, I have provided a brief overview of our view of the environmental issues which have formed the basis in part for S. 1925.

These issues have been discussed in great detail before this committee and others. Therefore, in the interest of time, I will not repeat them at length here today.

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Suffice it to say that our knowledge of the role that coal-fired powerplants play in such environmental issues as acid rain is still evolving, and we must balance the benefits of accelerated research and development and its associated cost against the timeframes associated with problems such as acid rain.

In general terms, there is a great degree of similarity between the elements of S. 1925 and the Department's ongoing Coal Research and Development Program.

Indeed, the Senator just a few moments ago testified that his bill would complement and incorporate the Department's efforts.

Our current Coal Technology Program encompasses the first two elements of the proposed legislation; specifically, coal process science and technology. They are essentially mirror images of our ongoing activities.

The Department's current budget calls for a 5-year program in fossil energy R&D, totaling $1.4 billion, of which some $821 million is earmarked for coal research and development.

This program includes the slate of technologies identified in the first two elements of S. 1925, as well as others such as coal liquefaction and gasification.

The National Energy Policy Plan recognizes a valid Federal role in this type of research and development; and that is, R&D directed at the initial stages of technology development.

In fact, the projected scope and funding levels described for the coal science and the process science and technology activities in S. 1925 will be met, or in some cases exceeded by a continuation of the administration's proposed program.

The major differences between S. 1925 and the administration's coal program resides in the third major component of the proposed legislation; specifically, engineering development

With the refocusing of the Federal Energy Program in 1981, we have shifted our research and development efforts away from large-scale engineering development toward more fundamental basic and applied research.

This policy was implemented to help ensure that the Government would not become a competitor to private initiatives in areas that were more appropriately private-sector responsibilities.

Within the context of this general policy framework, we believe S. 1925 offers the following benefits to the development of an improved national capability for using coal:

One, the multiyear nature of the proposal provides a stable budget framework. This would give both Government and industry research managers greater assurances in planning long-term research efforts.

I might say at this point, Mr. Chairman, that coming from the industrial sector, I have a special appreciation for the advantages offered by a stable, multiyear corporate commitment to an R&D effort. I believe the same holds true for Federal Research and Development Programs.

A second benefit offered by the bill is that it encourages private-sector involvement; a highly desirable factor in leveraging limited Federal dollars and in shaping research projects that ultimately will be commercialized by private firms.

We would encourage the sponsors of the legislation to provide as much flexibility as possible in choosing specific concepts for development. And I think the drafters have attempted to do this. These decisions are most properly made by private firms reading marketplace signals, rather than government through legislation.

In this regard, we are concerned that by designating several specific utilization processes to be pursued, S. 1925 does not provide adequate attention to all sectors of the energy-consuming marketplace.

Specifically, in the areas of coal utilization the legislation focuses primarily on utility applications, rather than on the industrial, commercial, and residential sectors.

Some utilization and gasification technologies can potentially have a greater impact in the smaller size ranges. We believe this should be pursued.

In some instances, we believe S. 1925 is overly optimistic regarding the timeframe necessary to reach specific technological objectives. This may be the case, for example, in the use of coal slurry mixtures in gas turbines and diesels.

We are also concerned about the use of specified Federal funds to support large-scale demonstration projects, particularly where such projects are already underway.

For example, the private sector, led by the Electric Power Research Institute, is preparing to construct 160-megawatt atmospheric fluidized bed combustion demonstration plant at Paducah, KY.

The private sector will cost-share as much as 85 percent of this estimated $200 million project, and will have the lead role in project management.

The Federal Government will provide $15 million in fiscal year 1985, and again in fiscal year 1986, as approved by Congress in the fiscal year 1984 Appropriations Act.

Likewise, the 100-megawatt cool water demonstration powerplant, due to begin operating near Daggett, CA, within the next few weeks, will provide the utility industry with the information necessary to make future commercial investment decisions regarding the coal gasification combined cycle power option.

The KilnGas system for producing a clean, low Btu gas from coal for use in utility boilers or in combustion turbines is now being tested at commercial scale in a privately financed project at East Alton, IL.

Test burns of coal-water mixtures have been conducted for durations of up to 35 days in an industrial boiler as part of an effort led by the Electric Power Research Institute. The test burns are the preamble to a full-scale demonstration burn of coal-water slurry in an electric utility boiler.

Several utilities, Florida Power & Light, for example, have begun their own programs to test coal-water mixtures in multihundred-megawatt powerplants. And there are other such examples.

In each of these cases, when the technology appeared to offer substantial benefits for future commercial application, the private sector has taken the lead in scaleup and demonstration activities.

In short, Mr. Chairman, as Secretary Hodel pointed out in his November 16, 1983, letter to Senator Byrd, the Department shares a concern regarding the need for an effective program that will allow the expanded use of our coal resources in an environmentally acceptable manner.

We would encourage the Congress, however, to examine the administration's current budget proposals as well as ongoing private activities before endorsing additional Federal funds for coal technology development.

Turning to S. 1278, the Magnetohydrodynamics Research, Development, and Demonstration Policy Act.

S. 1278 would provide for an accelerated MHD Program leading to a major proof-of-concept demonstration project at an existing powerplant.

As I pointed out on page 13 of my formal statement, there are still several unresolved technical issues associated with MHD. Individual components and subsystems of the MHD power train are at various stages of development.

S. 1278 provides one approach to deal with these issues. The Department, as you're aware, Mr. Chairman, has recommended a somewhat different approach in its fiscal 1985 coal budget.

I would interject at this point, Mr. Chairman, that MHD represents one of those areas where we have gotten the message from the Congress.

Our MHD program, proposed to be funded in fiscal 1985 at some $17.8 million, would focus on bringing the individual components and subsystems of the MHD power train to comparable levels of technical maturity and would begin a cost-shared, proof-of-concept effort.

We want to work with the industrial sector to design, construct, and operate a coal-fired MHD combined cycle test unit sized, in our view, at an approximate scale of 80 megawatts of thermal input or approximately 20 megawatts of electric power generation. Eight megawatts would be generated by the MHD portion of the system.

This scale, we believe, would be sufficient to give private industry the information needed to make future commercial development decisions. However, we are presently discussing this and other program issues with the MHD industry.

S. 1278, on the other hand, specifies a facility of no less than 50 megawatts of electric power generation from the MHD system. That is substantially more than the Department's proposed facility.

S. 1278 also is specific in regard to retrofitting an existing electric powerplant. The DOE program would utilize existing test facilities.

Cost-sharing will be an important indicator of the private sector's commitment to the development and eventual application of MHD technology. We are pleased, therefore, to see that it is an integral part of both proposals.

Beginning on page 15 of my formal statement, I provided additional comparisons between DOE's program to that of S. 1278. In short, while S. 1278 focuses on an appropriate end-objective—that is, scale up to a larger retrofit MHD facility by industry, we believe it adds unnecessary cost and considerable technical risk in bypassing an intermediate scale, integrated system test.

We believe that the Department's proposed MHD R&D Program leading to such an intermediate-scale test facility is a more prudent approach and, therefore, is preferable to that prescribed in S. 1278.

This completes my remarks, Mr. Chairman. I'd be pleased to answer any questions.

[The prepared statement of Mr. Vaughan follows:]

THE DEPARTMENT OF ENERGY'S POSITION

on

S. 1925 — A BILL TO ESTABLISH A NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT PROGRAM

and

S. 1278 -- A BILL PROVIDING FOR ACCELERATED RESEARCH, DEVELOPMENT, AND DEMONSTRATION OF ELECTRICAL PRODUCTION FROM MHD

Testimony by

WILLIAM A. VAUGHAN
Assistant Secretary for Fossil Energy

to the

Subcommittee on Energy Research and Development
Senate Energy & Natural Resources Committee

April 9, 1984

Mr. Chairman and Members of the Subcommittee,

We are pleased to appear before you today to provide the Department of Energy's comments on two legislative proposals: S. 1925 - THE NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACT; and S. 1278, the MAGNETOHYDRODYNAMICS RESEARCH, DEVELOPMENT, AND DEMONSTRATION POLICY ACT.

Both proposals are intended to help foster the nation's technological capability to utilize coal, our most abundant fuel resource, in our future energy supply mix. Before commenting specifically on each of the bills, I would like to describe in more general terms the role we believe coal can -- and must — play in achieving our national energy policy objectives.

THE POLICY FRAMEWORK OF THE FY85 COAL BUDGET

The Department of Energy's FY 1985 coal research and development budget request has been fashioned from the basic principles established by the 1983 National Energy Policy Plan.

To achieve its primary goal of "fostering an adequate supply of energy at reasonable costs," the Policy Plan sets forth two strategies: a) to minimize Federal control and involvement while maintaining public health and safety and environmental quality; and b) to promote a balanced and mixed energy resource system.

The FY 1985 coal program is oriented primarily toward the second strategy — to promote a balanced and mixed energy resource system. To do this, a high priority has been placed on improving the competitiveness of coal in markets currently dominated by oil and gas. Coal comprises more than 88 percent of the nation's recoverable fossil energy resources, yet supplies less than 25 percent of the country's primary energy, while our least abundant resource — oil — continues to be the nation's dominant fuel source. Clearly, the U.S. must make better use of its coal resources if it is to achieve a balanced and mixed energy resource system.

In accordance with this objective, the President's fiscal year 1985 budget request reflects a commitment to establish a stable and productive federal funding level for coal research and development. Our FY 1985 coal budget of $178 million represents a 75 percent increase over the FY 1984 request. Although this amount is less than the level actually appropriated last year, it represents a major step toward compromise with the Congress.

This effort by the Administration to increase funding for coal research over past requests, particularly in light of the continuing national necessity of maintaining fiscal constraint, should be recognized in reviewing legislative proposals, such as those being discussed today, that would add even larger amounts of public funds to the national coal research effort.

Turning to the specific legislative proposals:

S. 1925 - THE NATIONAL COAL SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACT

S. 1925 would establish a 5-year program to accelerate the development of new and advanced technologies for the expanded use of coal in an environmentally acceptable manner. As the bill's primary sponsor, Senator Robert Byrd, said in introducing the legislation:

> "There is a renewed interest emerging in coal research and development... sparked by the heated public debate over the causes and consequences of acidic deposition in the Northeastern United States."

Because the origins of the proposed legislation are based on the role advanced coal technologies could play in reducing suspected acid rain precursors, a brief review of the acid rain issue is an appropriate starting point for a discussion of this bill.

The following points are particularly important:

First, there is little question that manmade contributions of sulfur oxides (SOx) and nitrogen oxides (NOx) play a role in the formation of acid precipitation. The question is "How much of a role?" The uncertainty is compounded by the fact that the scientific community cannot say with any degree of accuracy how much of a reduction of SOx, NOx, and other emissions from any source — local or distant -- will reduce acid rain, or its impacts, at any one receptor location.

On the other hand, we can say with a greater degree of certainty that neither the level nor trend in adverse effects attributable to acidic deposition is of sufficient magnitude to constitute an emergency situation. Available information suggests that current acidification levels, particularly in the most sensitive regions of the U.S., are not changing rapidly, and that gives us confidence that the time needed for additional research and further development of control methods will not entail a serious risk of adverse effects.

Finally, the U.S. has already taken significant action to improve the quality of its air and water. In response to the Clean Air Act, one of the most stringent environmental laws in existence, American industry has spent more than $150 billion on air pollution control. That, coupled with increased use of coal washing and low-sulfur coal, has resulted in a decrease of emissions of sulfur dioxide by 25 percent during the last decade. In all likelihood, these emissions will begin a second significant decline as older power plants are replaced by cleaner ones around the turn of the century.

These are important points because they provide a framework for balancing the benefits of accelerated research, and its associated costs, against the timeframes associated with the acid rain problem.

In general terms, there is a great degree of similarity between the elements of S. 1925 and the Department's ongoing coal research and development program (particularly when coupled with the current in-boiler sulfur/nitrogen control technology efforts of the Environmental Protection Agency).

S. 1925 would establish a 5-year, $775 million coal technology program focused on three areas:

Coal Science — a comprehensive effort to understand coal structure and process chemistry;

Process Science and Technology — a comprehensive research program to develop new and advanced technologies for coal preparation, precombustion cleanup of flue gases, post combustion cleanup, and several advanced utilization processes;

Engineering Development — a broadly based effort to produce, within 5 years, processes and coal systems at scales large enough to permit commercialization.

By comparison, the Department's current coal technology program encompasses the first two elements of the legislation — coal science, and process science and technology. These research and development activities are an integral component of the National Energy Policy Plan. The Department's current budget calls for a five-year program in Fossil Energy R&D totaling $1.337 billion of which $821 million is earmarked for coal research and development. This program includes the slate of technologies identified in the first two elements of S. 1925 as well as others such as coal liquefaction and gasification.

The National Energy Policy Plan recognizes e valid Federal role in research and development directed at the initial stages of technology development. Federal R&D focused on basic research through proof-of-concept serves two critical purposes:

First, it advances the frontiers of scientific and technical knowledge and provides the fundamental understanding necessary to support technological innovation. Second, it increases the range of alternative energy options available to the private sector by providing new scientific approaches and engineering concepts.

In fact, the projected scope and funding levels described for the "Coal Science" and "Process Science and Technology" activities in S. 1925 will be met, or in some cases exceeded, by a continuation of the Administration's proposed program as contained in the President's FY 1985 budget request.

The major difference between S. 1925 and the Administration's coal research and development program resides in the third major component of the legislation — engineering development. With the refocusing of the Federal energy program in 1981, the Department of Energy and EPA shifted their R&D efforts away from large-scale engineering development and toward more fundamental basic and applied research.

The policy of concentrating Federally-funded activities at the early stages of technology development — those stages not likely to be pursued by industry alone — was implemented to help ensure that the government would not become a competitor to private initiatives in areas that were more appropriately private-sector responsibilities.

The pace of commercialization and marketing of new technologies is affected by a variety of factors — overall energy costs, environmental standards, resource availability, public acceptance, corporate investment strategies, etc. Because the government will likely be neither the seller nor the customer for new technologies, it is not in the best position to make the market-driven decisions necessary to select one technology over another. If it attempts to do so, not only may the wrong technology be selected but the government's presence could discourage or eliminate the initiative of competing private firms that may be pursuing similar concepts.

Within the context of this general policy framework, we believe S. 1925 offers the following benefits to the development of an improved national capability for using coal:

1) The multi-year nature of the proposals provides a stable budget framework that would give both government and industry research managers greater assurances in planning longer-term research efforts;

2) The bill encourages private sector involvement, a highly desirable factor in leveraging limited Federal dollars and in shaping research projects that ultimately will be applied commercially by private firms;

We would encourage the sponsors of the legislation to provide as much flexibility as possible in choosing specific technological concepts for development. These decisions are most properly made by private firms reading marketplace signals, rather than by the government through legislation.

In this regard, we are concerned that by designating several specific utilization processes to be pursued (direct combustion of coal for process heat and steam, atmospheric and pressurized fluidized bed combustion, gasification/combined cycle, fuel cells, diesel engines, and gas turbines), S. 1925 does not provide adequate attention to all sectors of the energy consuming marketplace. Specifically, the legislation focuses primarily on utility applications, rather than industrial, commercial, and residential sectors. Recent studies have shown that some of the utilization and gasification technologies can potentially have a greater impact in the smaller size ranges.

In some instances, we believe S. 1925 is overly optimistic regarding the timeframes necessary to reach specific technological objectives. For example, the bill would mandate the development of "ready to use and fully characterized transportable coal fuels such as coal mixtures for use in various equipment such as boilers and combustion engines." While this objective is almost certainly achievable for boiler applications -- and indeed, is a part of our current program -- the timeframes will probably be somewhat longer for combustion engines such as gas turbines and diesels. Complete fuel specifications for the use of coal-liquid mixtures in these engines will likely be achieved through a two-part, parallel approach -- that is, the simultaneous development of materials/end use equipment and novel economically and environmentally acceptable slurry techniques. In this area, additional time (perhaps to the mid 1990s) will likely be required to achieve the research objectives in the most cost-effective and technologically sound manner.

We are also concerned about the use of specified Federal funds to support large scale demonstration projects. As previously stated, these projects should be the responsibilities of the private sector.

In some cases, demonstration efforts specified in S. 1925 are already underway. For example, the private sector, led by the Electric Power Research Institute, is preparing to construct a 160-megawatt atmospheric fluidized bed combustion demonstration plant at Paducah, KY. The private sector will cost-share as much as 85 percent of this estimated $200 million project and would have the lead role in project management. The Federal government will provide $15 million in FY 1985 and $15 million in FY 1986, as approved by Congress in the FY 1984 Interior and Related Agencies appropriations Act.

Likewise, the 100-megawatt Cool Water demonstration power plant, due to begin operating near Daggett, CA, within the next few weeks, will provide the utility industry with the information necessary to make future commercial investment decisions regarding the coal gasification/combined cycle power generating option. The private sector has assumed all of the financial risk for the construction of this project, with the U.S. Synthetic Fuels Corporation providing a price support for the operational phase.

The KilnGas system for producing a clean, low-Btu gas from coal for use in utility boilers or combustion turbines is now being tested at commercial scale in a privately financed project at East Alton, IL.

Test burns of coal-water mixtures have been conducted for durations of up to 35 days in an industrial boiler as part of an effort led by the Electric Power Research Institute. The test burns are the preamble to a full-scale demonstration burn of coal-water slurry in an electric utility boiler. Several utilities — Florida Power and Light, for example — have begun their own programs to test coal-water mixtures in multi-hundred megawatt power plants.

In addition to these ongoing projects, several other efforts are being planned by the private sector to demonstrate new technological concepts that are included in the proposed legislation.

In each of these cases, when the technology appeared to offer substantial benefits for future commercial application, the private sector has taken the lead in scale up and demonstration activities.

The Department, therefore, would caution against providing Federal funds for projects that essentially would duplicate ongoing development efforts funded by the private sector.

For example, a provision of the bill would authorize a product improvement effort for state-of-the-art scrubbers, specifically to lower costs and increase system availability. This is an area that clearly does not appear appropriate for a Federal role but rather lies within the province of the private sector. It, in fact, is perhaps the major thrust of the Electric Power Research Institute's post combustion cleanup program.

Similarly, the proposed regenerable scrubber demonstrations have essentially been accomplished with the development and application of the Wellman-Lord process and the current demonstration effort of the Aqueous Carbonate process.

Finally, the specific budget amounts provided by the legislation should be carefully examined, particularly in light of the current national need to restrain Federal spending. The Department continues to advocate a program focused principally on research efforts that would enhance the general knowledge base for coal, rather than supporting specific technological development that benefits only one company or one segment of the industry.

As Secretary Hodel pointed out in his November 16, 1983, letter to Senator Byrd, the Department shares a concern regarding the need for an effective program that will allow the expanded use of our vast coal resources in an environmentally acceptable manner. The Secretary went on to state that such a program could build upon ongoing activities in the Department of Energy's coal program.

Given, however, the (1) current efforts of the Department to establish a wide range of technical options from which industry can choose; (2) ongoing industry demonstration activities; (3) the relatively slow trends of damage from acid precipitation, if such trends exist; and (4) the paramount need in the near term to maintain fiscal constraint across the Federal government to continue the momentum of economic recovery, we would encourage the Congress to examine the Administration's current budget proposals as well as the current privately-initiated activities before endorsing additional Federally-funded efforts in coal science, technology, and development.

S. 1278 - THE MAGNETOHYDRODYNAMICS RESEARCH, DEVELOPMENT, AND DEMONSTRATION POLICY ACT

S. 1278 would provide for an accelerated program of research, development, and demonstration with respect to the production of electricity from magnetohydrodynamics, leading to the construction and operation of at least one major proof of concept demonstration project in connection with an existing electric powerplant, and for other purposes.

After the investment of nearly $450 million of public funds and approximately $50 million of private funds during the past 10 years, the magnetohydrodynamics (MHD) development program has reached a significant decision point. Individual components and subsystems of the MHD power train are at various stages of development. For example, the oxygen (air separation) plant and the DC/AC inverter are essentially commercial hardware or are readily adaptable to an MHD power system. The durability of the nozzle and superconducting magnet also appear to be sufficient for power generation at commercially required durations. Other components, however, such as the combustor, have not undergone sufficient testing to judge performance, reliability, and durability. Some critical issues, such as seed regeneration, electrical isolation, and boiler performance, require additional experimental data. Finally, several theoretical scale-up uncertainties remain, for example, in electrodynamic flow instabilities.

Facilities and, in some instances, subscale experimental components are available to answer most of these questions in a reasonable time. S. 1278 provides one approach to deal with the remaining issues. An alternative approach, however, has been recommended in the Department's proposed FY 1985 coal technology budget:

DOE's Proposed Proof-of-Concept Development Program

The FY 1985 DOE budget request has proposed a significant realignment of the MHD program. The Federal MHD effort, proposed to be funded in FY 1985 at $17.8 million, would focus on bringing the individual components and subsystems of the MHD power train to comparable levels of technical maturity and would begin a cost-shared, "proof-of-concept" development effort.

The principal objective of the program will be to work with the industrial sector to design, construct, and operate a coal-fired MHD combined cycle proof-of-concept test unit. The proposed plant would integrate each major component of the power system — combustor, channel, superconducting magnet, inverter, and heat recovery/seed recovery and regeneration system. The test facility would be sized at an approximate scale of 80 megawatts of thermal input or approximately 20 megawatts of electric power generation. This scale, we believe, should be sufficient to give private industry the information needed to make future commercial development decisions; however, we are presently discussing this and other program issues with industry.

Cost-sharing will be an important indicator of the private sector's commitment to the development and eventual application of MHD technology. Therefore, it is an integral part of the proposed "proof of concept" program. The amount of industrial cost-sharing will determine the schedule of the program. If no cost-sharing is available, the clear indication will be that the technology has not developed sufficiently to permit private financial risk-taking. If this is the case, the Department would reorient its efforts to improve the scientific and technical understanding of the MHD concept rather than proceeding with a concurrent proof-of-concept facility. On the other hand, if significant private sector financing is made available, a clear signal will be given that MHD technology holds sufficient market potential to warrant the Federal involvement needed to bring the technology to a level of technical maturity necessary for future private investment decisions.

Comparison of DOE's Program to S. 1278

The principal differences between the development efforts proposed by DOE's FY 1985 budget request and S. 1278 are:

- S. 1278 specifies a facility of no less than 50 MW electrical from the MHD portion of the process (the "topping cycle") while the DOE "proof-of-concept" facility would be sized at approximately 8 MW of electrical generation from the MHD topping cycle and about 20 MW electrical overall (or a total of about 80 megawatts thermal);
- S. 1278 specifies operation of the facility by 1992. The schedule of the DOE proposed program would be determined, in large measure, by the willingness of industry to share the costs of the facility;
- S. 1278 specifies that no more than 60 percent of the funding be borne by the federal government. The DOE program is based on a recommended level of cost-sharing by the federal government of 50 percent, with adjustments to the scope and schedule of the program to be made depending upon the level of industry support;

- o S. 1278 is specific in regard to retrofitting an existing electric powerplant. The DOE program would utilize existing test facilities. Both approaches would transmit MHD-generated power to a utility grid;
- o S. 1278 requires the establishment of a Technical Review Panel. The DOE program does not propose to address the details of program management until an indication of industrial involvement can be obtained.

As in any development effort, a judgement must be made as to the proper pace of large-scale development efforts compared to continued laboratory and benchscale research. A program which concentrates solely on laboratory research, combined with theoretical analyses and limited, highly instrumented, subscale, parametric component tests will eliminate much uncertainty but could result in a longer development effort. On the other hand, an effort focused on engineering development will proceed at much greater technical risk, but at a more rapid pace toward eventual commercial development if no major technical problems are encountered.

By proposing a multi-pronged effort, with parallel activities in scientific research and in engineering development, the Department believes it has recommended a program which incorporates a prudent mix of effort. With few exceptions, even the most mature MHD components and subsystems require extensive efforts to reduce the risk of an unsuccessful and unnecessarily costly expenditure of funds for an integrated MHD test system.

This, therefore, is the rationale for the Department's position that a scientific program coupled with the start of cost-shared design efforts for an intermediate scale "proof-of-concept" test facility, represents a prudent and cost-effective use of public funds. Moreover, we have been encouraged by the willingness of private sector proponents of MHD technology to view our proposed program on its technical merits and to enter into open and candid discussions with the Department.

While S. 1278 focuses on an appropriate end objective, e.g. scale-up to a larger retrofit MHD facility by industry, we believe it adds unnecessary cost and considerable technical risk in bypassing an intermediate integrated system test in order to demonstrate the technology at a larger scale within a mandated period of time.

We believe that the Department's proposed MHD R&D program leading to an intermediate-scale test facility is a more prudent approach and is preferable to S. 1728.

This completes my formal statement, Mr. Chairman. I will be pleased to answer any questions the Committee may have.

Senator **Domenici**. Thank you very much, Mr. Secretary.

I gather then that it's your opinion that the Department already has many of the authorities which are conferred under the bill that we're considering today. Is that correct?

Mr. **Vaughan**. Yes, sir, that is correct.

Senator **Domenici**. Now, it seems to me that you're doing much of what they would have us do in the research side, but you're not doing what they direct on the demonstration side, except perhaps in the case of MHD, and you have explained the difference in sizing.

You have, nonetheless, a demonstration proposal in MHD and also in the atmospheric fluidized beds. Do you expect to be doing more projects of this type if there is a substantial interest on the part of the private sector?

Mr. **Vaughan**. Yes, sir. I think one of the real advantages of substantial interest on the part of the private sector is that they come forward in a joint-venture interest with their dollars and we can leverage the public dollars that you gentlemen in the congress have seen fit to appropriate.

I think that's the ideal situation, where we are able to get more bang for the buck, so to speak.

Senator **Domenici**. I have just one request for the record and then I will yield to the Senators who are here.

The Department is proposing a program to initiate design and engineering development of an integrated coal-fired MHD plant at the 80-megawatt thermal level.

Would the Department provide the subcommittee with an overview of the technical areas concerning this project for the record?

Mr. **Vaughan**. I would be more than happy to, Senator, yes, sir.

[The information follows:]

TECHNICAL ASPECTS OF THE PROPOSED MHD PROOF-OF-CONCEPT FACILITY

The proposed 80 Mw(t), integrated MHD test system is comprised of two fully integrated subsystems, an MHD topping cycle and a steam bottoming cycle. The overall plant layout is prototypical of an early commercial plant design in that intermediate-temperature (1200°F), oxygen-enriched air will be used as the oxidizer (fully developed and more efficient MHD plants are expected to employ high temperature (2900°F) air as the oxidizer). Detailed calculations of plant performance indicate that if the 80 Mw(t) Integrated MHD/Steam Test Facility were to be operated as a complete "mini-plant", its gross electric output would be about 20 Mw (6 to 8 Mw from the MHD topping cycle and about 12 to 14 Mw from the bottoming steam turbine).

As presently contemplated, the MHD topping cycle of the integrated plant will be pressurized to approximately 6 atmospheres, will be electrically isolated, and will be capable of being operated continuously for an extended period (2000 hours or more). The MHD generator will incorporate a supersonically operated, diagonally connected channel, a superconducting magnet capable of continuous operation at a magnetic field strength of up to 6.0 Tesla, and all power conditioning electronics necessary to optimally interface the channel with the inverter component. To minimize project costs it is proposed that an existing superconducting magnet, currently in storage at the Argonne National Laboratory, be made part of the 80 Mw(t) topping cycle; that the existing inverter at the CDIF be modified or augmented to handle 6 to 8 Mw; and that all other DOE MHD resources be utilized to the maximum extent possible (where it would be cost effective).

In contrast to the topping cycle, no major steam bottoming components now exist for direct utilization in the 80 Mw(t) test facility. Therefore, the heat recovery and seed recovery (HRSR) subsystem will be a "grass roots" plant, incorporating all critical elements necessary for the simulation of early, commercial MHD/steam combined cycle systems. Specifically, the HRSR subsystem will provide for all hardware necessary for steam raising/recovery, seed, ash and slag collection, seed recovery and slag/ash mixtures, environmental effluent control, and ancillary components (settling ponds, cooling towers, etc.). The detailed design of the HRSR subsystem will provide all elements necessary for subsystem integration and its ultimate integration with the topping cycle.

Senator DOMENICI. Senator Ford.

Senator FORD. Thank you, Mr. Chairman.

I have about four questions that Senator Bradley would like to ask Secretary Vaughan. And I would ask the Secretary if he would give Senator Bradley and the committee an answer to his questions in writing? I'll submit those for the record.

Mr. VAUGHAN. I would be more than happy to, Senator.*

Senator FORD. Mr. Secretary, if S. 1925 were enacted and fully appropriated as an addition—underscore, as an addition to the current level of fossil R&D program activity, the total appropriation would still be less than that appropriated in either 1981 or 1982, would it not?

Mr. VAUGHAN. I believe that's correct, sir.

Senator FORD. I see everyone's shaking their heads, so maybe I'm correct. It would still be less if you fully enacted or appropriated this bill, it would still be less than your budget request for fusion or for fission research and development, would it not?

Mr. VAUGHAN. I think you're right. I'm not familiar with the specific numbers on fusion or fission, but I assume the staff has given you the right numbers.

Senator FORD. Well, maybe I could have gotten it on my own. [Laughter.]

Mr. VAUGHAN. Yes, sir.

Senator FORD. You know, some of us do work up here when we have good staff, too, you know?

Mr. VAUGHAN. That you or your staff got, Senator.

Senator FORD. Well, you're beginning to get right there now, Mr. Secretary.

On March 22, this year, you testified before the House Subcommittee on Fossil and Synthetic Fuels. You described this administration's criteria for when it would provide funds for projects beyond the proof-of-concept stage. You said, and I quote, "A private sponsor must be willing to provide an equal or predominant share of the project's cost before the Department will be willing to consider such a proposal," end of quote.

Why do you arbitrarily insist on private industry paying at least half? Are you flexible at this point at all?

Senator DOMENICI. He'd settle for 48 percent.

Mr. VAUGHAN. Senator, I think that remark was made with regard to the demonstration and commercialization part of the entire R&D chain. And you recall, that chain starts with very basic research; moves up through proof-of-concept, which is the area we believe that it is most appropriate for Government involvement. It then moves on toward engineering demonstration and commercialization which we believe are more appropriate in the hands of the private sector.

While I stated in that testimony, and in some discussion that followed thereon the considerations you have mentioned, I do not want this to indicate that this administration is lock-step on these matters at all. This is what we would like to do. This is what we think should be done. That's a negotiating target.

Each R&D project, it seems to me, has to be handled in an ad hoc manner on its own merits, with its own specific considerations.

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*See Appendix I.

So I would like to erase any consideration that that's a hard-fast, no, never. That is not the case.

Senator **Ford**. Does this apply to the 11 projects then in S. 1925?

Mr. **Vaughan**. I think it would, Senator. I think it would apply to anything. And, by the way, if we could get more than 50 percent funds, we're more than happy to. In fact, I just extolled the virtues of an 85/15; and, frankly, there are several that are 100 percent private sector, and, certainly, the Government ought not get in those.

So I think it's a full range. And here we're talking about—or at least in our testimony, our ideals as we saw it.

Senator **Ford**. Would you consider any of the 11 to be commercialized, or would you—how would you describe their scale, pilot, or demonstration size? Are they semiworks, or whatever you call them?

Mr. **Vaughan**. Most of the specifics listed in the legislation, if I understand the thrust of your question, we are involved with now. And in that sense, the legislation incorporates what the Department is doing.

I don't recall other specific projects, but I'd be glad to characterize them for you, Senator.

Senator **Ford**. If you would, I'd appreciate it, Mr. Secretary.

[The information follows:]

ENGINEERING DEVELOPMENT PROJECTS LISTED IN THE BYRD BILL

The attached lists the engineering development projects in the Byrd bill; its characterization and the current state of the technology for each project.

The National Coal Science, Technology and Engineering Development Act Engineering Development Program

Project	Characterization & Technology Status
1. Construct a fine coal preparation and cleaning process facility of no more than 500 tons per day (the facility should be constructed in such a fashion as to allow the addition of advanced chemical coal cleaning).	This project can be characterized as a test facility at which advanced coal cleaning processes would be evaluated. Two flexible coal cleaning test facilities of the desired size (500 tons/day) are in place. EPRI has erected and is operating such a facility at Homer City, PA. Also, the facilities at Ames National Laboratory, Ames, Iowa, could be modified to accommodate advanced chemical coal cleaning add-ons. DOE has proposed in the FY 1985 budget request to test advanced physical cleaning devices at the EPRI test facility at Homer City, PA. We believe that the state-of-the-art is such that several advanced physical concepts which offer significantly improved performance over today's technology are ready for this type of testing and that more can be ready in the near future. We do not believe that any chemical cleaning processes are ready for this type of testing, but that design of a chemical proof-of-concept system could begin in late FY 1985.
2. Retrofit an oil-fired boiler of at least 100 MWe using deeply cleaned coal.	This is a demonstration project. The technology for retrofit application has been advanced to a point where the private sector can fund a demonstration in a more accommodating boiler design. The critical element of any application is the development of advanced coal cleaning technologies.
3. Demonstrate a regenerable flue gas desulfurization system of at least 50 MWe.	This can be characterized as a demonstration project. The Wellman-Lord regenerable FGD system has already been commercialized at full scale. A 100 Mw Rockwell International Aqueous Carbonate Process demonstration is underway at Niagara Mohawk Power at Niagara Falls, NY. Cosponsors of the test include DOE, EPA, EPRI, New York State ERDA and the Empire State Electric Energy Research Corporation.

Project	Characterization & Technology Status
4. Demonstrate a combined SO_x (sulfur dioxide)/NO_x (nitrogen oxide) removal system of at least 50 MWe.	This is a demonstration project. Technologies being considered for combined SO_x and NO_x include: - E-Beam with lime sprayer is under test at TVA Shawnee plant at approximately 10 Mw scale. Testing has been conducted for a few weeks time with promising results. - E-Beam with ammonia has been tested in Japan. Construction approved for a 10 Mw scale in Indiana, but has not been started. - Copper oxide with ammonia has been tested by DOE at less than 1 Mw scale. Test results are promising and an attenuation problem has been determined and solutions are practical.
5. Conduct a furnace retrofit of in-boiler sulfur control technology of at least 50 MWe.	EPRI, cosponsored with Southern Services Co. and EPA are planning such a demonstration of the Limestone Injected Multi-Stage Burner (LIMB) process in a 200 MWe demonstration unit. EPRI plans to demonstrate the LIMB process initially in a smaller 40-100 MWe demonstration unit. If the initial demonstration is successful EPRI will follow with another application on a 400 MWe plant. DOE will test a hydrated lime system at 25 Mw size in a small utility on low sulfur coal only.
6. Demonstrate an atmospheric fluidized bed combustion system of at least 100 MWe.	This is characterized as a demonstration project. There are approximately 60 industrial sized AFB units in operation today. Although there are currently 18 U.S. boiler manufacturers offering AFB technology for industrial use on a commercial basis there are no commercial utility units in operation. TVA is operating a 20 MWe AFB utility pilot plant at its Shawnee plant in Puducah, KY. This pilot plant has logged approximately 5,000 operating hours. TVA is also presently completing plans for a larger 160 MWe AFB demonstration unit at the Shawnee Plant.

Project	Characterization & Technology Status
7. Demonstrate a repowering application of a pressurized fluidized bed combustor of from 50 to 100 MWe.	This size unit is characterized as a demonstration project. The U.S. in cooperation with the U.K. and West Germany operates a 80 MWt PFB facility in Grimethorpe, England. This facility provides large scale combustion performance data. PFB technology test rigs at New York University and NCB/CURL, England, provide combustion characterization, effect of scale-up component design and performance of alternate fossil fuel performance data on gas turbine corrosion and erosion effects in a PFB combustion environment.
8. Demonstrate a repowering application of combined cycle coal gasification of from 50 to 100 MWe.	This is characterized as a demonstration project. Two combined cycle demonstration plants, in operation or soon to be in operation, when completed should provide the private sector with the necessary data to evaluate the process. The first of these is the 100 MWe Coal Water Coal Gasification Program which will demonstrate on a commercial scale the viability of integrating coal gasification technology with combined cycle power generation technology. The plant located in Daggett, CA, is scheduled for start-up in June 1984. A second combined cycle process being demonstrated is the Kilngas Coal Gasification. A 50 MWe oil boiler at the Wood River Generating Station, Illinois Power Co., East Alton, IL, will be modified to accommodate the process.
9. Develop and test a coal-fueled gas turbine in a second generation combined-cycle system of at least 50 MWe.	This is characterized as a demonstration project. The technology is in the preliminary engineering test phase at bench scale. Investigations are being conducted on coal/water mixture preparation, combustion, and deposition/corrosion/erosion of blading. Considering the work that must be accomplished prior to demonstration tests, there is doubt that this can be achieved by 1990.

Project	Characterization & Technology Status
10. Develop and test an industrial scale coal-fueled gas turbine suitable for industrial cogeneration of at least 5 MWe.	This is characterized as a proof-of-concept project. The technology is in the preliminary engineering test phase at bench scale. Investigations are being conducted on coal/water mixture preparation, combustion, and deposition/corrosion/erosion of blading. Considering the work that must be accomplished prior to demonstration tests, there is doubt that this can be accomplished by 1990.
11. Test a utility phosphoric acid fuel cell system using coal-derived gas at a size of 10 to 50 MWe.	This is characterized as a demonstration project. There are two phosphoric acid fuel cell projects underway that are in the pre-prototype stage. One is a 4.8 MWe project at Con-Ed and another by TEPCO in Japan. However, to date fuels for the phosphoric acid fuel cells have been limited to naptha and natural gas.

Senator **Ford**. Let me ask you this then. If the Government chose to expand the resources to undertake those 11 projects, would it likely accelerate the use of coal in the United States in the future?

Mr. **Vaughan**. I think that any soundly conceived R&D effort is likely to do that, Senator, certainly. And I think these are certainly reasonable proposals; so, yes, I think it would increase the use of coal.

Senator **Ford**. Well, is the administration's problem with S. 1925 chiefly a budgetary problem? There really isn't a technical problem here.

Mr. **Vaughan**. I think it's chiefly two areas. The main area of concern is budgetary. And, I think there is some concern that we not get too far into this business of commercialization and in large engineering and development projects. I think they are the areas of our concern.

The rest of that legislation I think we have little to no problems with, and I hope my testimonies indicate that.

Senator **Ford**. Well, you indicate now every place I hear the administration and Department talking on the fluidized bed at Paducah, KY, at Shawnee, what got you so interested in that this year when you weren't interested in it last year?

Mr. **Vaughan**. Perhaps the Congress did, Senator. I, as you know, sir, was not in this seat last year.

Senator **Ford**. I understand that, but it's just as warm this year as it was last year. [Laughter.]

Mr. **Vaughan**. I've been trying to cool it off, Senator.

Senator **Ford**. Well, you're doing a better job, I think, and we're awful glad that you accepted the $30 million that the Approriations Committee put into fluidized bed to match all the outside money that was coming. And when it was signed into law, I was right pleased that that was acceptable.

I'm afraid if it had been a line item veto it may not have gone through.

I thank you, Mr. Chairman.

Senator **Domenici**. You're welcome, Senator.

Senator Melcher.

Senator **Melcher**. Secretary Vaughan, I want to commend the Department of Energy, under Secretary Hodel, for its turn-around position on MHD.

Instead of being zero budgeted this year there's $17.8 million requested in the President's budget for MHD research and development.

I was pleased to hear you say that you want to look at these projects in a multiyear frame. The failure to do so has been significant during the past several years on MHD. While the Congress looked at MHD research and development as a multiyear project, the Department zero budgeted the program for several years. The program, therefore, lacked the necessary coordination, continuity, and essential planning focus that goes along with those two elements. Without this, I think, some money has been wasted.

There doesn't seem to be any question but what the electrical-use load projection nationwide will continue to grow.

Despite out efforts at conservation, it seems only practical to plan to meet projections of load growth. There have been no new nuclear powerplants ordered for several years. We continue to build coal-burning plants.

Doesn't it make sense for the Federal Government to take an aggressive lead then in research and development of such projects as MHD?

Mr. VAUGHAN. Yes, I think it does, Senator. And I think we are acting aggressively, particularly having gotten the message from you gentlemen in the Congress that you think MHD is something we should pursue with vigor. So I think we're doing that.

Senator MELCHER. Well, the appropriations each year for the past several years has been $30 million for the program. And while inflation eats away at that and makes $30 million less each year in purchasing and paying for research and development, still the administration's budget figure is $17.8 million.

That seems to lack aggressiveness, Mr. Secretary.

Mr. VAUGHAN. Let me try to come back at that, Senator, in this manner. In the last 10 years the Government has spent about, if I recall, $450 million in public funds in the MHD effort. The private sector has spent about $50 million. At this stage in the game, we find ourselves with a technology which has several major components in various states of maturity. One of the things we thought we ought to do is let the technology provide this answer to the Congress' interest.

So, when this budget was put together, we looked at what we had accomplished, and what we thought we needed to accomplish and put together our proposal, which was some $18 million to go to the community to begin negotiations. We also made clear to the Congress that it was in the nature of an opening position for discussion, and that's where we are. In fact, we have had one meeting with the MHD community. We hold the second meeting, which is open to the public, this Thursday afternoon. We will begin to shape where we are going to go with this technology. Frankly, I don't know at this stage.

The MHD community will undoubtedly come in and, in fact, has already given us some ideas of what they might think. And quite candidly, they are proposing a much larger facility. But I think at this meeting on Thursday we are likely, as in any negotiation, to start moving from the two ends. So, I look forward to that meeting. We'll find out what, both our minds and those with a substantial interest in the private sector and the university community think we should do about this technology.

I foresee a series of meetings with this community until we meet our promise to come back to the Congress and tell you gentlemen what the specific proposal is.

We have described that $18 million as our opening, or negotiating position, or strawman, as with any negotiation. So I cannot tell you at this time where we will end up. And we will be back before you Members of Congress with the results of those negotiations.

Senator MELCHER. I hope I'm not grasping at straws, Secretary Vaughan, in feeling encouraged by your comments and your meeting with the MHD community later on this week.

Your testimony is somewhat encouraging, too. You mention it appears that the superconducting magnet and the inverter are properly designed and engineered for scaling up to commercial size, or hopefully so.

But then you get back to the other units, such as the combuster and the channel and the question of fee recovery and seed recovery.

Now, it's clear from your testimony that you feel in those areas very basic research and development is necessary. Is that not correct?

Mr. VAUGHAN. We think some more work has to be done, yes, sir. I wish I could tell you everything was in an equal state of maturity. Unfortunately, with a complex subject like MHD, on many tracks, it's not surprising that we're at different stages. But I think we're at the point now we should bring everything up as rapidly as possible and then make the plunge in a test series.

And I can't promise you that would work either, but I think we're at the point where it is a prudent and reasonable risk, and I think most of the community feels that way.

Senator MELCHER. That comment also is encouraging. But I want to stress that I believe it has been the view of this committee, and of the Congress, that in the basic research, development and engineering we believe government takes the lead.

What steps has the Department of Energy taken in discussing MHD with the Synfuels Corporation?

Mr. VAUGHAN. We haven't had discussions, Senator, and I think it's because it's not fair to describe MHD as a synthetic fuel. It simply, in my judgment, is not. And if MHD is going to be brought to fruition, it seems like to me it's going to be done not by the Synfuels Corporation, but by the Department of Energy with the private sector.

Senator MELCHER. Mr. Secretary, whether it's fair or unfair, in authorizing the enabling legislation for the Synfuels Corporation, MHD was identified as a synthetic fuel by definition so that we wouldn't come up against this type of response. If we're going to appropriate that much money out of the Tressury for synthetic fuels, we thought it wise to include MHD by definition as a synthetic fuel.

Mr. VAUGHAN. I am informed, Senator, that the Energy Security Act did have such a provision in it, and we will have to pursue that interest with the SFC.

Senator MELCHER. I'd be delighted if you did, because at the outset of this administration, I visited with the newly appointed—I don't even think he would have been confirmed at that time—Secretary of Energy, to discuss exactly this question.

Now, 3 years and some months later, we have to remind the Department of Energy that this opportunity exists and that Congress saw fit to make that opportunity available.

I find it inconceivable that we have to penny ante this type of research and development when the funds are already authorized.

Now, I might point out, Secretary Vaughan, that while I'm pleased that this budget year has increased the amount over the last couple of years for fossil research and development, we're still talking about $273 million in R&D for fossil, and $483 million for fusion, and $618 million for nuclear. Clearly, coal is still sucking the hind teat—not to coin a phrase, but it's the appropriate phrase at the right point. [Laughter.]

We'd like to get off of that hind teat and up in the midmainstream of the nurturing of research and development.

Let me ask one other thing, and that's this: your critique of S. 1278 seems to hinge on size and whether we go to a retrofit of a 50-megawatt size generation capability for MHD. I don't think we're far apart. I don't think the Department of Energy and S. 1278 is all that far apart.

The question really comes down to do we still use in the component integration facility small size components, or do we start to plan now to get to a retrofit? I think both can go on almost simultaneously, or I hope that's the case. I think that with a little more funding they could go on simultaneously.

We set a deadline in S. 1278 for 1992. Do you find that to be presumptious or pie-in-the-sky sort of thinking?

Mr. VAUGHAN. I think it's going to be a little longer than that, Senator, before it's commercial. We think it will probably be roughly the turn of the century before that technology goes fully commercial.

I don't want to imply that I think we ought to slacken effort just because it's out there a little ways. MHD offers some very significant advantages if the concept proves out. So I think we should continue to pursue it, but I don't think it'll come quite as soon as 1992.

Senator MELCHER. I think, Secretary Vaughan, you're in a very fine position this year to lay out the program schedule. I want to work with you on that. S. 1278 is that beginning, as far as I'm concerned, on laying out a schedule. But it has to be done with your cooperation.

I'm pleased that you will be meeting with the private sector MHD community this week, and I hope to consult with you sometime before the month of May is out to see what we can do about completing an MHD program roadmap, as it were, and seeing whether it's 1992 or the year 2000. If we can still keep somewhere between 1992 and the year 2000, I think we will be doing a great service jointly for the country in bringing on this very significant technology.

I thank you very much.

Mr. VAUGHAN. Fine, Senator. I look forward to working with you on it.

Senator WARNER. Mr. Chairman, may I go on next?

Senator DOMENICI. Yes, indeed.

STATEMENT OF HON. JOHN W. WARNER, A U.S. SENATOR FROM THE STATE OF VIRGINIA

Senator WARNER. Mr. Chairman, thank you for calling these hearings. I think this is an important proposal. I regert I was detained elsewhere and couldn't be here at the time our distinguished colleague Senator Byrd testified.

Mr. Chairman and members of the committee, it's my intention to cosponsor this bill. I am concerned, however, about the price tag, but rough calculations, Mr. Chairman, and I wonder if you and I might discuss this, indicate that it's likely that we will appropriate sums comparable to what's requested under this bill in the ordinary appropriations process.

You're serving on that committee, as well as chairman of the Budget Committee, I wonder if you could address your thoughts of the fiscal impact of this proposal.

Senator DOMENICI. Well, Senator, let me just put it this way——

Senator WARNER. You see, Mr. Vaughan's from Virginia—Lynchburg, which is the heart of fiscal conservatism in my State, and since I'm going to sit up here and oppose him strongly on this, I want the message to go back home with a little more clarity than perhaps the Secretary's presenting here.

Senator DOMENICI. He's done pretty well, specially when you consider that testimony with reference to new legislation has to go to OMB before he gets to talk. He's done mighty well. He's a good soldier and hasn't said anything about that.

I think the answer generally would be correct to your statement.

If that is the relevant issue, do you want to authorize in this level in an area and at a dollar figure which the appropriators are apt to appropriate under existing law, then I guess one would have to ask what are the merits and demerits of being as precise as this legislation seeks to be. And I think that is a serious question. When you list 11, 12, 15 projects with specificity in terms of demonstration, you have a little bit of trouble.

Senator WARNER. I think, Mr. Chairman, members of the committee, that with all due respect to the originator, Mr. Byrd, that perhaps we can work with this piece of legislation to build in some more flexibility with respect to the various technologies.

I know I have been interested in coal-fire locomotives and, hopefully before this thing is finally acted upon we have a little recognition of that project and perhaps others.

So you have assured me the price tag might not be as high——

Senator DOMENICI. Might not be any higher than we would probably appropriate.

There's one other item in addition to the list which you just addressed in terms of flexibility. I only raise it because I'm not an expert in the area but, obviously of the 11 listed, 5 are clearly already being done by the private sector. And that kind of problem comes up. And there's the other philosophical issue of, do you mandate cost-sharing and, if so, how.

Senator WARNER. I don't want to take up the time of the committee here, Mr. Chairman. I only wish that our former colleague, Senator Jackson, was present today, because the principal motivation for me to join this bill, despite my interest in coal and my concern about the decline of this industry and the failure on behalf of the executive branch and the legislative branch to give proper stimulus to the coal industry, and that's a fact, I mean we're both guilty on that, but it's the national security aspects, Mr. Secretary.

I spent an undue amount of time, or a great deal of time on the questions of giving our Navy the ability to get our goods overseas, bring our goods in. And now we're into, in my subcommittee, of which Mr. Jackson was a member, the space aspects of the military, and ocean surveillance and things of this nature which, in the coming decade point at greater and greater risk to our reliance on importing all types of things; be it minerals or energy. And the more quickly that this Nation can proceed to become self-dependent on energy and these other vital sources, the more comfortable that I become.

And it's for that reason, the national security implications of this important piece of legislation that I'm going to throw my full and strong support behind it and see if we can't get it into law.

Senator DOMENICI. Thank you very much, Senator.

Senator WARNER. Mr. Chairman, one last question.

I was interested to hear—Mr. Secretary, could you clarify the Department's position in helping private industry to share the cost of prototypes. What is your policy now?

Mr. VAUGHAN. Senator, let me describe the ideal situation and point out that ideals are just targets you shoot at. As I said earlier here in a question about rigidity, that we're not rigid on these matters. Each R&D project, or each concept I think has to be looked at on its own merits and on an ad hoc basis, and then try to apply this concept to it.

Ideally, we think it is appropriate for the Federal Government to be involved in the high-risk R&D. That's where it's involvement ought to be greatest. In fact, in some things maybe in total.

As you move from that initial work toward eventual commercialization, ideally you'd like to phase the Government out. As you move closer to the point where business should make the decision and the choices among the alternatives, the Government, in our view, should certainly not be in control, and should be much less involved.

That's the basic approach we believe ought to be applied. We have said in the Department with respect to fossil energy that we believe we should go from the basic all the way through the proof of concept. And at that point you're in the position to start making some decisions about building a full-scale prototype. And we think that basically should be done by the private sector.

But even in those terms there are shades of gray. So there's nothing absolute, nothing magic, right or wrong, in my view, about any of these concepts. I think the Government should start with the high-risk things the private sector cannot afford to do and move toward the place where the private sector can move these technologies into the marketplace. They're better reacting to market signals than the Government. I think that's what we're talking about.

Then, of course, against that we always have the backdrop of what can we afford to do in any given year or series of years? And how you make that call is not easy for a Secretary or the President or for you gentlemen in the Congress. As you know, it's give and take.

I see nothing absolute about any of those concepts. We're perfectly willing to work in this program, and when the Congress has acted, and the President has signed something into law, our duty shifts, and it's to implement it in the best, most efficient manner possible. We're ready to do that.

Obviously we're here, as Senator Domenici said, trying to support the budget request which our boss thought appropriate as he did that balancing act. And I think that's appropriate, but consistent with whatever the Congress and the President may ultimately decide to do.

Senator **Warner**. Mr. Chairman, I'd like to have a complete statement placed in the record.

Senator **Domenici**. That will be done.

[The prepared statement of Senator Warner follows:]

OPENING STATEMENT OF SENATOR JOHN W. WARNER
APRIL 9, 1984
SENATE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SD-366

MR. CHAIRMAN, I COMMEND YOU FOR HOLDING THIS HEARING ON S. 1925, "THE NATIONAL COAL SCIENCE TECHNOLOGY AND ENGINEERING DEVELOPMENT ACT," AND S. 1278, "THE MAGNETOHYDRODYNAMICS RESEARCH, DEVELOPMENT AND DEMONSTRATION POLICY ACT OF 1983".

I PARTICULARLY WANT TO COMMEND THE DISTINGUISHED MINORITY LEADER FOR HIS SPONSORSHIP OF S. 1925. ONCE AGAIN, HE IS TAKING THE LEAD IN LEGISLATION OF VITAL IMPORTANCE TO THE COAL INDUSTRY AND INDEED, TO THE ENERGY INDEPENDENCE AND CONTINUED ECONOMIC RECOVERY OF THE UNITED STATES.

MR. CHAIRMAN, THE ECONOMIC HISTORY OF COAL MINING IS ONE OF PEAKS AND VALLEYS. TODAY, THE COAL INDUSTRY IS IN A DOWNTURN WITH NEARLY 30,000 UNEMPLOYED COAL MINERS IN THE APPALACHIAN REGION ALONE AND OVER 70,000 UNEMPLOYED NATIONWIDE.

THE TRADITIONAL MARKETS FOR AMERICAN COAL ARE NOT EXPANDING. THIS LACK OF GROWTH IN THE COAL MARKET PERPETUATES THE UNEMPLOYMENT MISERIES OF THE AMERICAN COAL INDUSTRY. AN IMAGINATIVE PARTNERSHIP BETWEEN PRIVATE INDUSTRY AND THE GOVERNMENT IS NEEDED TO GIVE NEW DIRECTION THE THE COAL INDUSTRY.

NEW MARKETS MUST BE CREATED FOR AMERICA'S COAL WITHIN THE UNITED STATES AND OVERSEAS. ENHANCED COAL TECHNOLOGY MAY BE THE KEY TO CREATING NEW JOBS FOR AMERICAN COAL MINERS BY INCREASING THE USE OF COAL IN AN ENVIRONMENTALLY SOUND MANNER.

(MORE)

THE NATIONAL COAL SCIENCE, TECHNOLOGY AND ENGINEERING DEVELOPMENT ACT WOULD ESTABLISH A PARTNERSHIP BETWEEN PRIVATE INDUSTRY AND THE FEDERAL GOVERNMENT TO ADVANCE COAL TECHNOLOGY. I COMMEND THE SPONSORS OF THE BILLS FOR THEIR LEADERSHIP IN THIS IMPORTANT AREA AND LOOK FORWARD TO THE TESTIMONY.

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Senator DOMENICI. Does anybody have any further questions of the Secretary?

[No response.]

Senator DOMENICI. Did you have anything further you wanted to put into the record?

Mr. VAUGHAN. No, sir. We will try to get the answers to written questions that have been submitted by the committee members quickly.

Senator DOMENICI. Very good.

Now, we're going to take the first panel, panel 1, Carl Bagge, Dwain Spencer, Dr. Jones, and Dwight Keating.

Senator Warner will take the Chair for about 25 minutes in my absence and then I will return. Senator Melcher, I understand, the second panel has a number of experts and witnesses with reference to MHD.

Senator MELCHER. That's correct.

Senator DOMENICI. I'm not sure that I'm going to be able to stay long enough for that, but I am more than willing to let you preside, if you can arrange it so that you could handle that this afternoon. I can't return, but we will accommodate you in some way.

Senator MELCHER. Thank you very much, Mr. Chairman. I will be able to stay.

Senator WARNER [presiding]. Mr. Bagge, members of the panel. Recognizing the time constraints, as recommended by the chairman, I hope you will accommodate the Chair and we will include, of course, without objection in the record your complete statements. Having had the benefit of the testimony by Senator Byrd and the administration, perhaps you might touch on those points that you feel you can amplify.

STATEMENT OF CARL E. BAGGE, PRESIDENT, NATIONAL COAL ASSOCIATION

Mr. BAGGE. Mr. Chairman and members of the subcommittee, I'm Carl Bagge of the National Coal Association. The association represents coal producers, coal sellers and other organizations associated with the Nation's coal industry.

I appreciate the opportunity to appear this morning in support of S. 1925, and thank the chairman for holding the hearing.

I have a very brief statement that I would like to present.

I would also like to take this opportunity to commend Senator Byrd for his consistent and outstanding leadership on behalf of coal for nearly three decades in the U.S. Senate.

The introduction of S. 1925 reflects Senator Byrd's judgment that now is the time—now is the time, as he said, to accelerate the development of these technologies that will allow coal to be burned more cleanly.

S. 1925 is an appropriate companion to S. 454, and together, we believe, form Senator Byrd's proposal to address the acid rain issue, which NCA supports. Now, we don't support acid rain legislation, we support the Byrd initiative and this administration's position. And this, it seems to me is a third leg of a three-legged stool—that is to say, mitigation of the problem, acceleration of research, and finally accelerating the technologies.

We believe that existing scientific uncertainties regarding the acid rain phenomenon must be adequately resolved before Congress considers any emission control strategy for coal-fired powerplants.

Senator Byrd's proposals embodied in S. 454 and S. 1925 present eminently more reasonable approaches to deal with acid rain in terms of the acceleration of the ongoing acid rain research programs, the acceleration of coal technology programs, and the appropriation of Federal funds for mitigation purposes.

We were delighted that the President, in his State of the Union Address, endorsed these basic principles of S. 454. And it seems to us that it took a great deal of political courage, indeed, for the President and this administration to adopt which was, in essence, Senator Byrd's initiative.

Furthermore, the Department of Energy's fiscal year 1985 budget request is consistent with many of the proposals considered in S. 1925.

We believe 1925 is compatible with the the thrust of the administration's coal R&D programs, which emphasize advanced coal combustion techniques. And it's in the combustion area that the challenge lies.

I can recall that 10 or 12 years ago when coal was discovered the oil embargo. The big challenge was production. And I can recall Dixy Lee Ray, asked by the President, as well as the Chairman of the AEC to put together a plan to prioritize our energy initiatives. And we had a tough time. We finally convinced the then Chairman of the Atomic Energy Commission that coal production was then the critical issue, because we didn't know how we could possibly produce the kinds of tonnages that we were talking about in 1973 with Project Independence, and we were talking about 1.5 billion tons by 1982 or 1983.

But the scene has shifted, it seems to me now to the utilization side, because, as you gentlemen are all aware, we have overproduction in the Nation today. This bill builds upon and accelerates over a 5-year period, which we're grateful for rationally approaching it over a 5-year period instead of trying to look at this issue annually on the ongoing activities within the DOE.

In this regard, Senator Byrd focused his bill on the need for more extensive, longer term research necessary to develop significant technological improvements.

S. 1925 is also consistent with EPRI's December 1983 report of the ad hoc committee to review the National Acid Precipitation Assessment Program.

The report states—this is the interagency task force that the Congress created in the Energy Security Act to look at the problem of acid rain.

The report states, and I quote, "The process of developing new control technologies for coal cleaning, combustion and cleanup should be central to the design of combustion systems."

Furthermore, S. 1925 would implement the report recommendation, and I quote again, "The DOE be given the task outside of the EPRI program to formulate a comprehensive and aggressive program in cooperation with industry for advanced control technology development," end of quote.

Senator Byrd made it clear when he introduced S. 1925 that it, and I quote him, "Would be a broadly based effort, carried out in conjunction with the private sector," end of quote.

And in endorsing S. 1925, we recommend that a provision relating to magnetohydrodynamics be included in the bill.

While DOE has provided funding for MHD in its fiscal year 1985 budget request, this represents a projected 40-percent reduction in the fiscal year 1984 budget.

The National Coal Association, therefore, supports the rapid development of MHD as warnings of assuring that coal is going more cleanly and more efficiently in the future.

Senator Melcher is to be commended, we believe, for his leadership, his outstanding leadership in proposing S. 1287 as an accelerated program to develop MHD.

In concluding, I would like to express our appreciation to Chairman McClure for scheduling oversight hearings on acid rain before the full committee on April 30. This committee has the responsibility to closely examine any legislative proposal that might adversely affect coal production, coal distribution, and coal utilization.

Thank you very much.

[The prepared statement of Mr. Bagge follows:]

STATEMENT OF
CARL E. BAGGE
PRESIDENT
NATIONAL COAL ASSOCIATION

on

S.1925 - THE NATIONAL COAL SCIENCE,
TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACT

BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

APRIL 9, 1984

Mr. Chairman and Members of the Subcommittee, I am Carl Bagge, President of the National Coal Association. NCA represents coal producers, coal sellers and other organizations associated with America's coal industry. I appreciate the opportunity to appear this morning in support of S.1925.

I would like to take this opportunity to commend Senator Byrd for his consistent and outstanding leadership on behalf of coal for nearly three decades in the United States Senate. The introduction of S.1925 reflects Senator Byrd's judgment that now is the time to accelerate the development of those technologies that will allow coal to be burned more cleanly. S.1925 is an appropriate companion to S.454 and together form Senator Byrd's proposal to address the acid rain issue which NCA supports.

We believe that existing scientific uncertainties regarding the acid rain phenomenon must be adequately resolved before Congress considers any emission control strategy for coal-fired power plants. Senator Byrd's proposals, as embodied in S.454 and S.1925, present eminently more reasonable approaches to deal with acid rain in terms of the acceleration of the ongoing acid rain research program (as set forth in the Energy Security Act of 1980), the acceleration of coal technology programs, and the appropriation of Federal funds for mitigation purposes. We were delighted that the President, in his State of the Union address, endorsed the basic principles of S.454. Furthermore, the Department of Energy's FY 1985 budget request is consistent with many of the proposals considered in S.1925.

We believe S.1925 is compatible with the thrust of the Adminstration's coal R&D programs which emphasizes advanced coal combustion techniques. This bill builds upon and accelerates, over a five-year period, relevant ongoing activities within the DOE. In this regard Senator Byrd focused his bill on the need for more extensive longer term research necessary to develop significant technological improvements.

S.1925 is also consistent with the EPA's December 1983 Report of the Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP). This report states that: "The process of developing new control technologies for coal cleaning, combustion, and clean-up should be central to the design of combustion systems . . ." Furthermore, S.1925 would implement the report recommendation " . . . that DOE be given the task, outside of the NAPAP program, to formulate a comprehensive and aggressive program, in cooperation with industry, for advanced control technology development." Senator Byrd made it clear when he introduced S.1925 that it" . . . would be a broadly based effort carried out in conjunction with the private sector."

In endorsing S.1925, we recommend that a provision relating to magnetohydrodynamics (MHD) be included in the bill. While DOE has provided funding for MHD in its FY 1985 budget request, this represents a projected 40% reduction from the FY 1984 budget.

NCA supports the rapid development of MHD as one means of assuring that coal is burned more cleanly and more efficiently in the future. Senator Melcher is to be commended for his leadership in proposing S.1278 as an accelerated program to develop MHD.

In concluding, I would like to express our appreciation to Chairman McClure for scheduling oversight hearings on acid rain before the full committee on April 30. This committee has the responsibility to closely examine any legislative proposal that might adversely affect coal production, distribution and utilization.

Mr. Chairman, I would be pleased to answer any questions.

* * * * * * *

Senator WARNER. Thank you very much.
Mr. Spencer.

STATEMENT OF DWAIN F. SPENCER, VICE PRESIDENT, ADVANCED POWER SYSTEMS DIVISION, ELECTRIC POWER RESEARCH INSTITUTE

Mr. SPENCER. Thank you, Senator. Mr. Chairman, distinguished members of this panel, it's a pleasure to address this committee relative to congressional initiatives being considered for the establishment of National Coal Science, Technology, and Engineering Development Program and an accelerated program of research, development and demonstration of electrical production for MHD, and to provide you a brief overview of the key R&D directions within the electric power industry as they relate to this Nation's bountiful coal resource.

I'm Dwain Spencer, vice president of the Electric Power Research Institute. In this capacity, I'm responsible for EPRI's coal conversion and advanced coal technology programs. In addition, I've served as a member of the Department of Energy's Fossil Energy Advisory Committee over the last 9 years.

As you know, Mr. Chairman, the electric utility industry is the Nation's largest user of coal of all types, consuming over 600 million tons of coal in 1983, or about 75 percent of all U.S. coal used.

This is a 40-percent increase over utility coal consumption just 10 years earlier. And we anticipate the electric utility industry use of coal will grow to over a billion tons per year by the year 2000.

Therefore, the electric utility's interest in consuming coal in an economically competitive, environmentally acceptable manner is an ever-growing priority requirement.

Research, development and demonstration of advanced coal utilization and conversion technologies is indeed a high priority over the next 5 to 10 years.

The initiatives being considered by this subcommittee can certainly assist the industry and the private sector in developing those most appropriate advanced technologies.

A very important point I'd like to make to the committee is that the electric utility industry has been strongly criticized by environmental groups on issues such as acid rain, fine particulate emission, solid wastes, and water use.

However, I would like to state unequivocally that the electric power industry, through EPRI, anticipated such requirements nearly 10 years ago, and has been sponsoring a broad research, development and demonstration program on advanced coal technologies to mitigate these problems.

In fact, the industry has continued to support the development of such advanced technologies as coal gasification combined cycle powerplants, atmospheric fluidized bed combustion, and coal liquefaction when the Department of Energy and many other private sector companies terminated their support for continued development of these technologies.

It is this continued commitment by the electric utility industry that I would like to highlight in my testimony.

I'd like now to just talk about three or four key technologies, if that's all right, Mr. Chairman.

The first in these technologies is coal gasification combined cycle powerplants. The gasification of coal to produce Syngas has been a key focus for the electric utility industry's advanced coal utilization for over 10 years.

The primary interest in this technology relates to its ability to permit essentially all of the inorganic and organic sulfur in the coal to be converted to reducing gas species such as hydrogen sulphide which can be easily removed from the Syngas.

Since most of the second generation coal gasification technologies of primary interest are operated at elevated pressures, they allow the gas treatment volume to be less than 1 percent of that from a conventional coal-fired plant; and, since they operate at elevated temperatures, also allow fine dust to be scrubbed from the Syngas with very modest cost increases for such plants.

Thus, a very clean gas, comparable to natural gas, with the exception of a lower heating value, can be combusted in a gas turbine combined cycle to produce electric power.

In addition, we have added another important emissions control capability to the process wherein very low NO-X emissions occur.

So in summary, coal gasification offers the promise for 99-plus percent removal of all sulfur species from the coal, essentially no measurable particulates in the stack, and nitrogen oxides emissions of less than 50 parts per million; a full order of magnitude reduction from present coal plants.

Thus, we see coal gasification-combined cycles as offering extremely attractive, environmentally sound way to utilize a broad range of U.S. coals, and most especially the high sulfur eastern and midwestern bituminous coals.

I term this the convergent technology, since once Syngas is produced, we can then produce a broad range of products and coal products as articles of commerce, ranging from electricity to petrochemicals, to fertilizer.

It is this unique electricity and coproduct market potential which has caused us to invest so heavily in the research, development, and demonstration relating to this technology, that is, over $100 million to date, with a projected additional $75 to $100 million over the next 5 years.

In this regard, I would just like to mention that we are nearing construction completion of the first integrated coal gasification combined cycle powerplant in the world near Daggett, CA, our so-called Cool Water project.

This plant utilizes the Texaco gasification technology in this federally coal-water slurry system utilizes slightly modified G combustion turbine combined cycle to produce approximately 100 megawatts of electric power.

We have designed the initial 5-year operational period, which will be initiated on the first of May of this year, to carry out tests on a wide range of U.S. coals, including the high-sulfur bituminous coals, and to clearly demonstrate the environmental superiority of this process and the performance and the economic potential of this technology.

Of course, Mr. Chairman, you're aware that this project received the first price guarantee from the Synthetic Fuels Corporation.

Although Cool Water is a big and important step in bringing coal gasification closer to technical and economic readiness, there is a strong need to demonstrate other gasification technologies, such as the British Gas Corp. Lurgi technology, Shell, and others in order to provide this country a broad stable of technologies capable of using all U.S. coal types for both new and retrofit applications.

I would hope that this could be one of the specific directions to be pursued by the Government, and that support for both the process development and electric generating systems would be supported under S. 1295.

I would like to just highlight two other technologies briefly.

Another key direction of EPRI's advanced coal utilization program is atmospheric fluidized bed combustion.

Again, EPRI has supported research and development on this concept for nearly 10 years, and has decided to proceed with a demonstration of this technology at approximately 160 megawatt scale in conjunction with TVA, Duke Power in the State of Kentucky.

Construction is to begin in 1985, with a 4-year testing program to commence in 1989.

As already stated this morning, the Congress has authorized DOE to provide approximately $30 million for this project, and DOE's financial support is greatly appreciated.

At the same time, we have been studying the practicality of atmospheric fluidized bed combustion retrofits of coal and oil dired units. A Northern States Power 15-megawatt oil-fired unit has been retrofitted with a fluid bed to burn wood chips.

Northern States Power and EPRI are now considering conversion of an existing 100-megawatt coal unit to 125-megawatt unit. And a third demonstration is under consideration by Colorado Ute and will utilize circulating fluid bed technology.

The experience from these projects should demonstrate a range of AFBC technologies for potential use by the electric utility industry in the mid-1990's.

Finally, I'd like to mention Open Cycle MHD. In written and oral testimony which I presented before the House of Representatives' Subcommittee on Energy Development and Application in both 1982 and 1983, I strongly recommended a continuing DOE Open Cycle MHD Program to support the activities at the Component Development and Integration Facility in Montana, the University of Tennessee Space Institute, and the necessary subsystem development programs to provide hardware for testing at these facilities.

I continue to believe that a Federal investment of $35 to $40 million annually for at least the next 3 to 5 years is warranted.

Such a program should focus on expanding an existing facility such as the CDIF into a fully integrated system test to assess the potential Open Cycle MHD technology. Wwithout such an integrated system test, in our judgment, the technical readiness of the technology will remain uncertain.

Depending on the success of this integrated systems test, it may be appropriate to develop a new larger scale facility.

In summary, we believe that Open Cycle MHD test facility data should be obtained and design studies conducted before a new facility commitment is made. If this were to become a key objective of the Department of Energy and EPRI activities, such definition should be forthcoming within the next 2 to 3 years.

In summary, I greatly appreciate the opportunity to testify before your subcommittee on such important topics. I truly believe "so goes the electric utility industry, so goes the country's energy and economic future".

Coal has, and will continue to play an ever-increasingly important role in the electric utility industry's future.

The development of modular, clean power systems in few hundred megawatt capacity increments is a key to the industry's expanded use of coal.

We, at EPRI, are committed to bringing such systems to commercial reality over the next few years.

An expanded Government role, coupled to industry, can only enhance the prospects of achieving this goal. We are delighted to see the initiatives being taken by this subcommittee and stand ready to work effectively with the Department of Energy in a meaningful implementation of that intent.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Spencer follows:]

REMARKS ON FEDERAL INITIATIVES AS RELATED TO THE ELECTRIC UTILITY INDUSTRY'S RD&D INTERESTS IN COAL

Dwain F. Spencer
Vice President
Advanced Power Systems Division
Electric Power Research Institute

Hearing on S1278 and S1925

Testimony Presented to:

Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C.

9 April 1984

I) Introduction

Mr. Chairman, it is a pleasure to address this subcommittee relative to Congressional initiatives being considered for the establishment of a national coal science, technology, and engineering development program and an accelerated program of research, development, and demonstration of electrical production for MHD and to provide you a brief overview of key R&D directions, within the electric power industry as they relate to this nation's bountiful coal resource. I am Dwain Spencer, Vice President of the Electric Power Research Institute (EPRI). In addition, I have served as a member of the Department of Energy's Fossil Energy Advisory Committee since 1976. Although these remarks are my own views, they are the result of EPRI's close working relationship with both the electric power industry and the DOE and ERDA fossil energy program over the last nine years.

As you know Mr. Chairman, the electric utility industry is the nation's largest user of coal of all types, consuming over 600 million tons of coal in 1983, or about 75 percent of all U.S. coal used. This coal produced approximately 55 percent of our total electric power in 1983 and was more than a 40 percent increase over utility coal consumption just ten years earlier. With the present difficulties of financing and licensing nuclear power plants, and limitations on the use of oil and gas for electricity production, we anticipate that electric utility industry use of coal will grow to over a billion tons per year by the year 2000. If our economy expands more rapidly than projected, it is conceivable that electric utility demands for coal will even exceed this estimate. Therefore, the electric utility industry's interest in consuming coal in an economically competitive, environmentally acceptable manner is an ever growing priority requirement. Research, development and demonstration of advanced coal utilization and conversion technologies is indeed a high priority over the next five to ten years. The initiatives being considered by this subcommittee can certainly assist the industry and the private sector in developing these "appropriate advanced technologies".

The electric utility industry has been strongly criticized by environmental groups on issues such as "acid rain", fine particulate emission, solid wastes, and water use. However, Mr. Chairman, I would like to state unequivocably that the electric power industry, through EPRI, anticipated such requirements nearly ten years ago, and has been sponsoring a broad research, development, and demonstration program on advanced coal technologies to mitigate these problems. In fact, the industry has continued to support the development of such advanced technologies as coal gasification combined cycle power plants, atmospheric fluidized bed combustion and coal liquefaction when the Department of Energy and many other private sector companies terminated their support for continued development of these technologies. It is this continued commitment by the electric utility industry that I would like to highlight in my testimony.

II) Key Advanced Coal Research and Development Directions for Electric Utility Industry Use of Coal

A) Coal Gasification Combined Cycle Power Plants

The gasification of coal to produce Syngas (carbon monoxide and hydrogen) has been a key focus for the electric utility industry's advanced coal utilization for over ten years. The primary interest in this technology relates to its ability to permit essentially all of the inorganic and organic sulphur in the coal to be converted to reducing gas species such as hydrogen sulphide which can be easily removed from the Syngas. Since the second generation gasification systems of primary interest, Texaco Partial Oxidation, British Gas Corporation-Lurgi (BGC-Lurgi) Slagging Gasifier, and the Shell Gasification Process, all operate at elevated pressures (300-600 pounds per square inch), the gas treatment volume is less than one percent of the volume of flue gas from a conventional coal-fired steam plant with scrubbers and the final form of the sulphur is elemental sulphur. Also since these units operate at elevated pressures, essentially all dust (fine particulate matter) which is carried over in the Syngas can be easily removed using Venturi scrubbers prior to the acid gas (hydrogen sulphide) removal process. Thus a very clean gas, comparable to natural gas with the exception of a lower heating value, can be combusted in a gas turbine combined cycle to produce electric power.

In addition, we have added another important emissions control capability to the process wherein very low NO_x emissions occur. In this approach, we saturate the Syngas with low temperature steam, produced in the initial Syngas cooling process, and reduce the maximum combustion temperature and, thus, nitrogen fixation during the combustion process. In summary, coal gasification offers the promise for 99+ percent removal of all sulphur species from the coal, essentially no measurable particulates in the stack, and nitrogen oxides emissions of less than 50 parts per million, a full order of magnitude reduction from present coal plants.

We have also evaluated the characteristics of the ash discharges from these units and find that these materials are extremely inert. Carefully conducted tests to assess the leachable metals from such ash discharges, which could be a concern under the Resource Conservation and Recovery Act (RCRA) have shown that heavy metal concentrations in leachates are at least an order of magnitude below those required to meet potable drinking water standards and two orders of magnitude below proposed RCRA requirements.

Thus, we see coal gasification-combined cycles as offering an extremely attractive, environmentally sound way to utilize a broad range of U.S. coals, and most especially the high sulphur eastern and midwestern bituminous coals. One final important point is that coal gasification is a unique technology on whom many diverse industries such as electric power, petroleum, and the chemical industry can depend in the future. I term it the Convergent technology, since once Syngas is produced, we can then produce a broad range of products and co-products as articles of commerce ranging from electricity to petrochemicals to fertilizer. It is this unique electricity and coproduct market potential which has caused us to invest so heavily in the R/D&D relating to this technology, i.e., over $100 million to date, with a projected additional $75 to $100 million over the next five years.

In this regard, I would just like to mention that we are nearing construction completion of the first integrated coal gasification combined cycle power plant in the world near Daggett, California, our Cool Water Project. This plant utilizes the Texaco technology and a slightly modified General Electric combustion turbine-combined cycle unit to produce approximately 100 MW of electric power. We have designed the initial 5-year operational period, which will be initiated on 1 May of this year, to carry out tests on a wide range of U.S. coals, including the high-sulphur bituminous coals, and to clearly demonstrate the environmental superiority of this process and the performance and economic potential of this technology.

We project that integrated coal gasification combined power plants, built in modules of 200 to 400 MWe capacity, will be directly competitive economically with large coal fired plants with stack gas scrubbers. As this technology develops, however, efficiency should improve further and provide cost savings over conventional pulverized coal technology. EPRI will serve as the bridge between this powerful new technology and the utility industry. In fact, a new utility industry group, the Utility Coal Gasification Association, consisting of 29 utilities, has been formed to enhance the communication of the results from Cool Water and other EPRI financed coal gasification technology results to the industry on a timely basis. In addition, this group is assessing various methods of introducing IGCC technology to minimize utility financial and technical risk.

Although Cool Water is a big and important step in bringing coal gasification closer to technical and economic readiness, there is a strong need to demonstrate other gasification technologies such as BGC-Lurgi, Shell, etc., in this country to provide a broad stable of technologies capable of using all U.S. coal types for both new and retrofit applications. I would hope that this could be one of the specific directions to be pursued by the Government and that support for both the process development and electric generating systems would be supported by DOE.

B) Atmospheric Fluidized Bed Combustion

Another key direction of EPRI's advanced coal utilization program is atmospheric fluidized bed combustion (AFBC). Again, EPRI has supported research and development on this concept for nearly 10 years and developed the basic understanding of the performance of these systems in a 6'x6' test facility constructed and operated for EPRI by Babcock and Wilcox (B&W). The performance and design data from this unit has provided the technical basis for the 20 MWe pilot plant built by B&W for TVA in Paducah, Kentucky. The pilot plant has essentially confirmed the earlier results.

EPRI has also decided to proceed with a demonstration of this technology, at approximately the 160 MWe scale, in conjunction with TVA, Duke Power and the State of Kentucky. Construction is to begin in 1985, with a four year testing program to commence in 1989. The AFBC Development Corporation, made up of the four principals, has been formed as a mechanism for other interested parties to contribute financially to this demonstration project. The Congress has authorized DOE to provide approximately $30 million for the project and DOE's financial support is greatly appreciated.

At the same time, we have been studying the practicality of AFBC's retrofit of coal and oil fired units. A Northern States Power (NSP) 15 MWe oil fired unit has been retrofitted with a fluid bed to burn wood chips. NSP and EPRI are now considering conversion of an existing 100 MWe coal unit to a 125 MWe unit utilizing a fluidized bed burner. A third demonstration project is under consideration by Colorado Ute and would utilize circulating fluid bed technology. This experience from these projects should demonstrate a range of AFBC technologies for potential use by the electric utility industry in the mid 1990s.

EPRI has identified as many as 200 other units in the industry that could benefit from this type of retrofit as an alternative to adding scrubbers. It should also be mentioned that we are increasing our analysis of the potential for retrofitting coal fired plants with Syngas, again as a better approach to limiting sulphur oxide emissions. However, these two alternate retrofit approaches will not be commercially available to the industry until the mid 1990s.

C) Coal Liquefaction

During the last 10 years, EPRI has also played a key role in defining, developing, and evaluating a broad range of coal liquefaction technologies such as H-Coal, the Exxon Donor Solvent Process, and Two Stage Liquefaction. In addition, we have conducted numerous tests to assess the combustion and emission characteristics of these fuels in boilers, combustion turbines, and diesel engines. In fact, we have spent over $100 million in attempting to develop clean, petroleum substitute fuels for the electric power industry and the nation.

At a time when nearly all of the major oil companies have terminated their research and development programs on coal liquids, we continue to support the only operating U.S. coal liquefaction pilot plant at Wilsonville, Alabama in conjunction with DOE and Southern Company Services. The recent advances at Wilsonville to improve both product yields and fuel quality (lower sulphur and nitrogen content fuels) has been exciting and rewarding. We continue to believe that direct hydroliquefaction offers the nation an important insurance policy in the event of import curtailments. As we look ahead, and see our nation's imports exceeding 8 million barrels per day by 1990, we continue to believe that both continued research and development on direct and indirect synthesis of liquid fuels is an important national priority. Again a federal initiative which hopefully will revitalize the nation's commitment to liquid fuel supply independence is an ever increasingly important requirement.

D) Open Cycle Magnetohydrodynamics (OCMHD)

In written and oral testimony which I have presented before the House of Representatives Subcommittee on Energy Development and Application in both 1982 and 1983, I strongly recommended a continuing DOE OCMHD program to support the activities at the Component Development and Integration Facility (CDIF) in Montana, the University of Tennessee Space Institute, and the necessary subsystem development programs to provide hardware for testing at these facilities. I continue to believe that a federal investment of

$35-$40 million annually for at least the next 3-5 years is warranted. Such a program should focus on expanding an existing facility such as the CDIF into a fully integrated system test to assess the potential of OCMHD technology. Without such an integrated systems test, the technical readiness of the technology will remain uncertain. Depending on the success of this integrated systems test, it may be appropriate to develop a new larger scale facility. I am presently not prepared to define the specific scale for a new facility, but have informed DOE that EPRI will work with them to define a meaningful test scale.

As I'm sure you are aware, EPRI has had a very modest R&D program in OCMHD, concentrating on the development of the MHD channel-inverter interface and the power conditioning of the inverter output to be compatible with electric utility system requirements. In addition, we have supported numerous design studies to estimate the performance and costs of potential commercial systems. Although I presently do not see a large economic "carrot" for this technology, high efficiency systems for utilizing coal in an environmentally acceptable manner clearly is in the national interest.

I would like to make one final comment on MHD systems which might make them even more attractive. We have been considering an approach wherein coal is first gasified, as discussed earlier, cleaned of its particulate and sulphur, and then fired either with oxygen or air prior to entering the MHD channel. This approach is similar to that being taken in the Soviet Union; however, we would be combusting Syngas from coal rather than natural gas. In this way, we could eliminate chemical regeneration requirements of the seed material and eliminate potential slag in the channel and downstream equipments. We are just embarking on an evaluation of this concept; however it may offer an interesting option to the conventional coal fired MHD approach.

In summary, we believe that integrated test facility data should be obtained and design studies conducted before a new facility commitment is made. If this were to become a key objective of the DOE and EPRI activities, such definition should be forthcoming within the next 2-3 years. With other advanced coal technologies emerging, it would appear that this would be a reasonable time frame for such a decision.

E) Other Emerging Coal Utilization Technologies

EPRI has also supported a broad range of other coal utilization or preparation technologies including flue gas desulphurization systems, coal cleaning, coal-oil and coal-water mixtures. Certainly the initiatives being considered by this subcommittee could further enhance the prospect that more satisfactory operating systems and experience will be obtained on these systems. However, it should be realized that these systems are more a "band-aid" approach being necessitated by environmental regulation than the more far sighted approaches discussed earlier in developing truly economic, environmentally clean systems in the future. I would hope that the relative balance in the R&D/D which would be carried out by DOE would favor the more advanced technologies.

III) Summary

Mr. Chairman, I greatly appreciated the opportunity to testify before your subcommittee on such important topics. I truly believe "so goes the electric utility industry, so goes the country's energy and economic future". Coal has and will continue to play an ever increasingly important role in the electric utility industry's future. The development of modular, clean power systems in few hundred megawatt capacity increments is a key to the industry's expanded use of coal. We, at EPRI, are committed to bringing such systems to commercial reality over the next few years. An expanded government role, coupled to industry, can only enhance the prospects of achieving this goal. We are delighted to see the initiative being taken by this subcommittee and stand ready to work effectively with the DOE in a meaningful implementation of that intent.

Thank you very much, Mr. Chairman, for the opportunity to address your subcommittee.

Senator WARNER. Thank you, Mr. Spencer.

Mr. Jones.

STATEMENT OF JAMES E. "MICKEY" JONES, JR., COMMISSIONER, ENERGY RESEARCH AND DEVELOPMENT, KENTUCKY ENERGY CABINET

Mr. JONES. Mr. Chairman, subcommittee members.

I'm J.E. Mickey Jones, Commissioner of Energy Research and Development, Kentucky Energy Cabinet.

I'm here today representing the energy cabinet and the Commonwealth of Kentucky. The cabinet appreciates the opportunity to take part in this, the first hearing, on this act.

I had hoped that the environment today would be such that I would be in the situation of preaching to the choir. Based on the remarks of the subcommittee, I find myself sitting among the choir, singing to the choir masters.

We come not only as the Nation's leading coal-producing State, but also as the State that has made the largest commitment of its own resources to coal research and development.

The experience we have gained during the last 10 years in carrying out our coal technology program will hopefully add to the deliberations on this bill.

My remarks will focus on the following areas: Kentucky's support for the bill in its intent; the importance of coal utilization to the economy and national security; the failure of past policy and programs to allow the potential of coal to be realized; need for accelerated coal utilization technology development, and application that will allow use of coal economically and meet environmental requirements.

Kentucky's activities in the past 10 years to develop new coal technology and the need to renew the State industry-Federal Government partnership in coal research and development.

That's a long list. And in the interest of time, I will give particular emphasis to the last two of these areas.

To our first point, the bill and its intent. It is a timely proposal. A Federal policy to maximize the use of coal has been, and remains an intelligent policy. What has been lacking is continuity of purpose.

We sense in this proposal a move toward a consistent and strategically focused program. A 5-year authorization for a mix of midterm and long-term goals could direct the appropriation process into a stable and more productive mode of support for coal research.

Kentucky fully supports the intent of this bill.

To our second point. Coal remains today as one of our most valuable but underutilized natural resources. Coal is the most economic of our major energy sources on a Btu basis; with the spread of the cost of a Btu of petroleum product to a Btu of coal now approaching 6 to 1.

The use of the most economic energy resource, coal, would have a major impact on our national economy and productivity.

In addition to the economic sense coal makes, there is a national security necessity. Although our consumption of Middle Eastern oil has declined at least temporarily, the recent presence of American forces in Lebanon and the Persian Gulf is a clear sign of our continuing vulnerability to interruptions in Middle Eastern oil.

The cheapest and quickest way to reduce our oil dependency would be to convert out powerplants, industries, and as Senator Warner suggested, some of our railroads, to more economical coal. Why haven't we done it?

The environmental restrictions on coal are such that we need a new generation of coal technologies which will not only meet environmental requirements, but also meet operational requirements.

We have found over the past 10 years in our own program that the development of technology is neither quick, nor easy, but it is possible. Progress has been made.

What is needed now is increased commitment and continuity. And that would be provided by the Coal Science Act.

To my third point. The failure, or at least limited success of past policy and programs. I address this program in some length in my written remarks; including an historical perspective and some quantitative information.

Gentlemen, you are as familiar as I with the shortcomings of our national coal policy over the past 15 years, and it has been discussed today here at length, so I will not dwell on this point.

However, I would note that the Japanese must think we're a very peculiar Nation. While we have the largest coal resource in the world, we move at a snail's pace in developing technology to use it.

While they, with no resource of their own, are scouring the world for technology to apply to Austrialian, Chinese, and United States coals. They have their own programs, as well as joint ventures with countries from which they plan to import coal.

While not fully utilizing our coal resources, we don't lose it because it stays in the ground, we simply miss an opportunity.

However, there is an equally important resource related to this bill that we are in danger of losing for all time, and that's not been discussed here today. That is the human resource, in trained, experienced coal researchers who are being forced out of their profession by funding reductions primarily in Federal programs. I know this firsthand from resumes that cross my desk daily, and from the reductions that we're going to have to make in our own research program.

Many of these people will be lost from the coal effort, and this is a tragic national loss. This bill could help correct that situation.

The fourth point of my remarks concerns how the act addresses the acceleration of coal utilization technology development and application.

This was also discussed here extensively today, and I will refer to my prepared statement and move on to my fifth point, which concerns the commitment that Kentucky has made to coal science and technology.

It is because of this commitment, as well as that of other States, that I believe congress should incorporate the States as partners in the implementation of this program.

Let me describe the intent of our commitment and the nature of our program. Ten years ago, the State of Kentucky undertook an innovative coal research and demonstration program.

As you know, your colleague on this subcommittee, then Governor, now Senator Ford, made a commitment to move Kentucky into the forefront of coal technology and utilization.

By 1977, Kentucky had completed construction of its own laboratory facility to house a coal research program. We have undertaken an extensive program in coal preparation, advanced combustion, and conversion technologies.

From the modest funding level of $200,000 in 1973, the State's budgetary commitment to our own coal R&D program has risen to $7½ million in 1983.

On the demonstration side we have participated in the successful operation of the Nation's largest direct liquefaction plant in Catlettsburg, KY, and a 20-megawatt atmospheric fluid combustion plant in Paducah, KY.

The total of which Kentucky has spent since 1974 on coal R&D of $70 million may not seem large in the national scheme or relative to the authorization envisioned by this bill, but let me assure you that for a State with one of the lower per capita incomes, it represents not only a significant sacrifice, but also a major hope.

The program was envisioned and begun as a partnership with industry and the Federal Government. However, the involvement of the Federal Government has been declining. This bill could turn that situation around.

Kentucky has maintained its commitment to coal R&D. It is ironic that the economic impact of the coal recession means that Kentucky's ability to carry out this program is reduced, and we must stabilize it at a somewhat lower level.

Our R&D program has sustained an approximate 30 percent budget cut for the next fiscal year.

For the past several years, we have carried out our program and paid for it ourselves, for the most part. It should be apparent that the States now need to be full partners in coal technology development, and the bill should recognize this need and opportunity.

Specifically, the wording in the act excludes the State by omission from the Coal Science Research Program. I will refer you to section 4, paragraph (b). The same language which excludes the States by omission is also in the Process Science and Engineering Research Program, section 5, paragraph (b). Also the status of the States' eligibility of the States is questionable under the Engineering Development Program, section 6, paragraph (b).

The sixth and final point I wish to make concerns the implementation of this bill. The act directs DOE to implement these two program through its traditional channels. Kentucky would propose that a new channel be opened and that Federal-State cost-sharing be pursued at all parts of the program. As Secretary Vaughan put it, "to get more bang for the buck."

Recent Federal policy has turned to tax and regulatory changes to stimulate industrial research and development, particularly of near-term technologies.

Federal research and development programs, specifically energies, have been reoriented to advanced high-risk and long-term payoff technologies.

The States have moved to fill the gap in the Federal approach between long-term and near-term prospects by sponsoring their own technology centers.

A trend has emerged, and has been documented by the Office of Technology Assessment, showing the States to be actively initiating the development of technology, sponsoring technology transfer and participating in demonstrations.

This State response can be attributed partly to natural economic forces and partly to Federal policies, but it capitalizes on the fact that States are closer to the ultimate users of new technologies and closer to the sources of innovation, our university systems.

I also want to stress our relationship with both coal producers and consumers, the users of new technology.

Coal States like Kentucky have ready access to coal cleaning, prep plants and powerplants. We understand the characteristics of our own coals. We have the capacity to evaluate processes and provide for direct technology transfer to the producer for improved coal preparation and utilization.

Virtually all of Kentucky's powerplants are coal fired, and Kentucky is deeply involved in scrubber technology. We are in an excellent position to bring together utility operating experience, laboratory experience to address improvements and reliability and performance.

Again, I wish to point to the States as the most appropriate partner in the mix to carry out this act.

The cost of this bill will perhaps be its most controversial aspect. For every ton of coal that is used instead of oil, up to $100 is saved. In simple calculations that I included in my written testimony, it shows that the program under this act will pay for itself many times over. In fact, you could recover the entire investment in the program in 1 year by a 1-percent increase in 1990 coal production. And I think that would be a modest achievement for a program of this type.

In economic savings alone would justify the program, and that doesn't include the national security implications.

In summary, coal offers this country a way to better ourselves economically and improve our security. New technology is needed, and the coal science and technology bill provides both the strategy and continuity required.

Kentucky supports this measure.

Mr. Chairman, I urge this subcommittee to bring in the States as partners with the energy technology centers, the national laboratories, the university community, and the private sector for the implementation of this act.

Thank you.

[The prepared statement of Mr. Jones follows:]

TESTIMONY PRESENTED TO
THE SUBCOMMITTEE ON ENERGY AND DEVELOPMENT
ON
SENATE BILL 1925
National Coal Science, Technology, and Engineering Development Act of 1983

BY
KENTUCKY ENERGY CABINET
James E. Jones, Commissioner
Department of Energy Research & Development
April 9, 1984

I am James E. Jones, Jr., Commissioner of Energy Research and Development, Kentucky Energy Cabinet. The Energy Cabinet appreciates the opportunity to take part in this first hearing on the National Coal Science, Technology, and Engineering Development Act of 1983. We come as not only the nation's leading coal producing state, but also as the state that has made the largest commitment of its own resources to coal research and development. The experience we have gained during the last ten years in carrying out our coal technology program will hopefully add to the deliberation on this bill.

My remarks will focus on the following areas:

- Kentucky's support for the Bill and its intent
- The importance of coal utilization to the economy and national security
- The failure of past policy programs to allow the potential of coal to be realized
- The need for accelerated coal utilization technology development and application that will allow use of coal economically and meet environmental requirements
- The failure of past policy programs to allow the potential of coal to be realized
- Kentucky's activities in the past ten years to develop new coal technology
- The need to renew the state, industry, federal government partnership in coal research and development.

To our first point: the Bill and its intent. It is a timely proposal. A federal policy to maximize the use of coal has been, is, and remains an intelligent policy. What has been lacking is continuity of purpose. We sense, in this proposal, a move toward a consistent and strategically focused program. A five year authorization for a mix of mid and long term goals could direct the appropriation process into a stable and more productive mode of support for coal research. Kentucky fully supports the intent of this bill.

To our second point: coal remains today as one of our most valuable but underutilized national resources. Coal is the most economic of our major energy sources on a Btu basis. The spread between the cost of a Btu of petroleum product to a Btu of coal is approaching six to one. The use of the most economic resource, coal, could have a major impact on our economy and productivity.

The major market for coal is for electric power generation and the only other alternate energy source to coal and oil is nuclear. We have seen the staggering escalation of the cost of nuclear plants and the termination of numerous projects over the past few years. Some of these cancelled nuclear projects are now looking at coal as an alternate fuel.

In addition to the economic sense coal use makes, there is a national security necessity. Although our consumption of middle eastern oil has declined, at least temporarily, the recent presence of American armed forces in Lebanon and in the Persian Gulf is a clear sign of our continuing vulnerability to interruptions in middle eastern oil. The cheapest and quickest way to reduce our oil dependency would be to convert our power plants and industries to more economical coal. There are also clear economic incentives for some of our transportation sectors to use coal. Coal could be used on the railways and waterways now, and on our highways in a few years. Why then haven't we done it? The environmental restrictions on coal are such that we need a new generation of coal technologies which not only meet environmental requirements but also meet users' operational requirements.

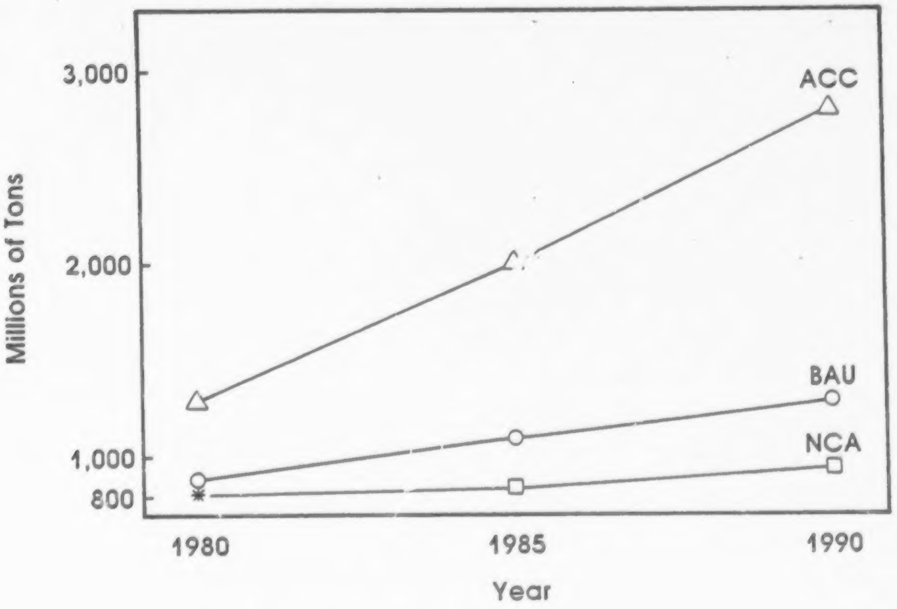
We have found over the last ten years that the development of such technology is neither quick nor easy, but is possible. Progress has been made. What is needed now is increased commitment and continuity, and that would be provided by the Coal Science Act.

To the third point: the failure (or limited success) of past policy and programs. Whether speaking of coal research or coal production--and the two are clearly linked--the circumstances of coal can be summed in a simple statement: "The trouble with the world today is that the future is not what it used to be."

"What it used to be" is well documented. A useful point of reference is ten years ago when coal was turned to as the hope for pulling the country out of the energy chaos the Oil Embargo created. The 1974 Coal Task Force for Project Independence established two sets of production targets as policy alternatives. The projected production levels are shown in the following figure. The first set of targets, termed "Business as Usual", simply relied on no excessive disruption to existing trends. The second set, the "Accelerated" production targets were based on several assumptions including "...accelerated research and development for advanced technologies of utilization and conversion of coal including stack gas scrubbers and coal gasification."

There was a trend in national coal policy in the 1970's to maintain more or less constant production goals while the time frame in which to achieve those goals continued to decrease. As an example, the National Energy Plan in 1977 estimated production similar to the Project Independence "Business as Usual" level by projecting 1.2 billion tons in 1985.

CONTRASTS IN COAL PRODUCTION SCENARIOS: 1980-1990



✱	Actual Production: U.S.D.O.E., Energy Information Administration
NCA	National Coal Association moderate growth forecast as of February 27, 1984
BAU	"Business as Usual" targets, Project Independence, Coal Task Force Report, November, 1974
ACC	"Accelerated" targets, also Coal Task Force, Project Independence

In a three scenario projection, the National Coal Association's forecast for the moderate growth case in coal production came to 854 million tons in 1985 and 1.1 billion tons for 1990. It should be noted that the NCA forecast levels are less than were projected ten years ago under the "Business as Usual" (that is no accelerated technology) development scenario. The production levels now projected for 1990 are less than half that believed possible ten years ago with an accelerated technology program.

Kentucky, the leading coal production state, must agree with the NCA's lowered expectations. The Energy Cabinet projects Kentucky production to be 158 million tons by 1985. Our production peaked in 1981 at 154 million tons. The combination of recession and low sulfur coal demand caused our production to drop 14 million tons to an estimated 140 million tons in 1983. The west Kentucky coalfield, part of the Illinois Basin, hit its peak production of 56 million tons in 1975, and has since registered a 31% decline because of its high sulfur coals.

We are not saying there hasn't been progress in coal technology in the past. There are examples that progress has been made including four operational synthetic fuel plants and two more starting up this summer. We have new, clean technologies for generating electric power in the pilot and demonstration stage. However, the rate of progress and the application of new technology has been such that we have not approached the targets established a decade ago. We need an accelerated effort and at least as important, continuity of effort.

The fourth point of my remarks addresses just that need for acceleration of coal utilization technology development and application.

Within each of the three research and development programs proposed, the language in the bill provides strong direction to the strategic effort. For example, the basic coal research program is to seek an in-depth understanding of coal structure and process chemistry with particular attention to the chemistry of the polluting species bound in the coal molecule. This program should be able to capitalize on basic work already done under USDOE's pulverized coal combustion program. A recently published technology assessment of that program states "basic investigation in the field appears to be approaching a transition to a realistic description of pulverized coal combustion...". If we are so near the payoff, then special emphasis on process chemistry is appropriate.

New processes of combustion such as FBC and various gasification technologies demonstrate that we can improve the competitiveness and reduce the risks of burning coal. Their status is recognized in directive language under utilization. But, it is also clear that major engineering and materials problems need to be overcome if we are not again to suffer a "failed future". These kinds of problems are specifically addressed under the terms of the Process Science and Engineering Research Program.

However, this raises my fifth point, the commitment Kentucky has made to coal science and technology. It is because of this commitment as well as efforts of other states that I believe the Congress should incorporate the states as partners in the implementation of this program.

Let me describe the extent of our commitment and the nature of our program. Ten years ago the State of Kentucky undertook an innovative coal research and demonstration program. As you know, then Governor--now Senator--Ford made this commitment to move Kentucky into the forefront of coal technology and utilization.

By 1977, Kentucky had completed construction of its own laboratory facility housing the Institute for Mining and Minerals Research. Since then the State has undertaken an extensive program in coal preparation, advanced combustion and conversion technologies. For example the laboratory operates both a 300 pound an hour fluid bed combustor and a 10 pound per hour liquefaction unit as part of an ongoing program to characterize and evaluate the behavior of Kentucky coals. From the modest level of $200,000 in seed money in 1973, the State's budgetary commitment to its own energy R&D program rose to $7.5 million in 1983. On the demonstration scale we have participated in the successful operation of the nation's largest direct liquefaction pilot plant in Catlettsburg, Kentucky, and a 20 megawatt atmospheric fluid bed combustion plant in Paducah, Kentucky. We have had several commercial scale plants fall victim to the malaise of that industry, but are participating in a planned 160 megawatt fluid bed demonstration project. The cumulative amount spent by the state since 1974 on the "R" part of R&D is $40 million with an additional $26 million spent on the "D" part. The total Kentucky has spent, some $70 million, may not seem large in the national scheme or relative to the authorization envisioned by this Bill, but let me assure you that for a state with one of the lower per capita incomes it represents not only a significant sacrifice but also a major hope. The program was envisioned and begun as a partnership with industry and the federal government. However, the involvement of the federal government has been declining.

The State has maintained its commitment to coal R&D. It is ironic that the economic impact of the coal recession means that Kentucky's ability to carry this program is reduced and we must stabilize at a somewhat lower level. Our R&D program has sustained an approximate 30% budget cut for the coming fiscal year. We have tried to offset these reductions with private sector funding. As a result, over the next four years, industrial sponsors will provide over $1.2 million to assist the continued development of our liquefaction program. We, and they, believe that liquefaction technology remains essential to our national security over the long-term and are committed to maintaining the effort to advance this technology. This program and this state developed Technology Center have earned national recognition but both now need a broader base of support.

The promise of liquid fuels from coal has been delayed and coal remains demand limited. We must look to the utility, industrial, and export markets in the short-term. Further expansions of the steam coal market--utility and industrial--will be very sensitive to the cost of each incremental step of environmental control. Producers, users, and their states have a common interest in moving ahead with the mid-term technologies which will control effluents better.

The sixth and final point I wish to make concerns the implementation of the bill. The Act directs DOE to implement these two programs through its traditional channels. Kentucky would propose that a new channel be opened and that federal/state cost sharing be pursued.

Recent federal policy has turned to tax and regulatory changes to stimulate industrial research and development, particularly of near-term technologies. Federal research and development programs, specifically Energy's have been reoriented to advanced, high risk and long-term payoff technologies. States have moved to fill the gap in the federal approach between long-term and near-term prospects by sponsoring their own technology centers. A trend has emerged and been documented by the Office of Technology Assessment showing the states to be actively initiating the development of technology, sponsoring technology transfer and participating in demonstrations. This state response can be attributed partly to natural economic forces and partly to federal policies, but it capitalizes on the fact that states are closer to the ultimate users of new technology and closer to the sources of innovation in the university systems.

I also want to stress our relationship to both coal producers and consumers--the users of new technology. Coal states like Kentucky have ready access to coal cleaning or prep plants, understand the characteristics of their own coals, have the capacity to evaluate processes and to provide for direct technology transfer to the producer for improved coal preparation. Similarly, virtually all of Kentucky's power plants are coal-fired and Kentucky is deeply involved in scrubber technology. Some are retrofitted; some are NSPS plants; some are coming on-line over the decade to meet even stricter limits. We would be in an excellent position to bring together utility operating experience with laboratory expertise to address improvements in reliability or performance.

Coal Chemistry, Process Science and Engineering Research Programs offer many opportunities for federal-state cost sharing. Kentucky's research and development program specializes in Kentucky coals. These are marketed widely to steam coal consumers. Advanced technology to characterize, prepare, pulverize, burn and convert Kentucky coal is not just a state interest, but a national interest as well. Again, I wish to point to the states as a most appropriate partner in the strategic mix.

The cost of this bill will perhaps be the most controversial aspect. However, the $775 million dollar price tag is small compared to either the cost of imported oil which was about $80 billion per year in 1981 and is now running at about $50 billion per year. The national return on the investment authorized by this Bill should not be anything less than spectacular. A "back of the envelope" calculation yields some interesting numbers. Assuming the current differential of coal and oil previously mentioned of about $5 per million Btu, there would be a savings of over $100 dollars per ton of coal used instead of oil. Thus, the technology developed under this Bill would have to add only 7.75 million tons (or less than 1% of the projected 1990 market) to recover in energy cost savings the entire program investment in one year. A one percent market expansion from technology developed by this Bill is a modest expectation and a one year payout period would satisfy even the most demanding investor. This is economic return alone, the national security factors would be similarly impressive.

In summary, coal offers this country a way to better ourselves economically and improve our security. New technology is needed and the Coal Science and Technology bill provides both the support and continuity required so that we do not again realize "failed futures" for coal. Kentucky supports this measure.

Mr. Chairman, I urge this Subcommittee to bring in the states as partners with the energy technology centers, the national laboratories, the university community, and the private sector for implementation of the National Coal Science, Technology, and Engineering Development Act.

Senator WARNER. Mr. Jones, that was indeed an important thing you pointed up about the cost and how it can be recovered. I hope that my colleagues will look at that. It makes it very helpful for those of us that are concerned about the expenditure side of our budget.

And I join you in your observation about your distinguished Member of the Senate who is present here today. There is no person in the Senate that knows more about coal technology and the uses of coal than the good distinguished Senator, Mr. Ford.

Senator DOMENICI [presiding]. Thank you, Senator Warner.

Dwight Keating, vice president of Grafton Coal, Clarksburg, WV.

STATEMENT OF DWIGHT KEATING, VICE PRESIDENT, GRAFTON COAL CO., CLARKSBURG, WV

Mr. KEATING. Mr. Chairman, members of the subcommittee.

I'm Dwight Keating, vice president of Grafton Coal, and cochairman of the Government Affairs Committee of the Mining and Reclamation Association of America, and the Director of the West Virginia Surface Mine Reclamation Association; both of which strongly support S. 1925.

In the interest of brevity, I'd like to cover just two points that have been addressed somewhat today.

First of all, the bill provides for a 5-year time horizon. This allows for proper planning, rather than this start-up-and-go characteristics that we've had for the last 15 years.

The second issue that I would like to address is the cost sharing, and why this is so difficult.

The coal industry itself is highly competitive. There is no shortfall of coal. If the price of coal goes up, you can bring on a new mine and the price of coal comes quickly down. There is no windfall profits in the coal industry.

How does the coal industry then spend its money in R&D? It has to have, first of all, a relatively short-term time horizon. We spent it, one, for safety. We have to comply with MSHA. And the safety regulations are often changing, and we must, therefore, develop new ways to improve safety in the mines.

No. 2, we spend it on reclamation. Through the Office of Surface Mining, we have had new demands put on the industry which have mandated that we spend more money on coming up with innovative reclamation techniques.

Third of all, we spend money on efficiency to improve efficiency in the mines. It's a highly competitive industry. If we do not improve efficiency, we will soon be out of business.

Therefore, these are the main areas that the coal industry, from a producing standpoint, spends its research and development. Therefore, we have very, very little money available to spend on how to improve the environmental aspects of the coal burning.

We turn to our users of coal; our main customer being the utilities. They have had over the last 10 years declining financial conditions. Their bond ratings have dropped. They also have to get rate increases through the PUC's or the PSC's, and they have very jaundiced eyes as commissioners, approving money for projects that may not pay off for 5 or 10 years in the future.

Therefore, there is a very strong constraint on both the producer of coal and the end-user of coal to spend as much as the administration would like on these demonstration projects. It is the nature of the industry, and it is not gong to change because of the competitive nature of the industries.

Therefore, we urge the committee to recommend expeditious passage of—mark up and passage of this bill, because it addresses the long-term needs of an R&D program that we have not had in a long time.

Thank you.

[The prepared statement of Mr. Keating follows:]

Statement*

Mr. Dwight Keating
Vice President, Grafton Coal Company
Clarksburg, West Virginia

on behalf of the

Mining and Reclamation Council of America
and the
West Virginia Surface Mining and Reclamation Association

before the

Subcommittee on Energy Research & Development
Committee on Energy & Natural Resources
United States Senate

on S. 1278 and S. 1925

April 9, 1984

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*This statement briefly outlines the need for an expanded federal role in the research, development, and commercialization of coal technology. A more comprehensive review of the history, need for, and status of coal research is contained in two attached articles from the January/February, and March/April 1984 issues of MARC's bimonthly magazine, LandMARC titled Coal Technology; Cleaning Up A Dirty Fuel; and, Is Coal Technology On Again?.

Mr. Chairman, members of the subcommittee, I am Dwight Keating, Vice President of Grafton Coal Company, Clarksburg, West Virginia, and appear today on behalf of the Mining and Reclamation Council of America (MARC) and the West Virginia Surface Mining and Reclamation Association (WVSMRA). MARC is a national association of surface coal producers, which through its corporate and affiliate members represents over 70% of domestic coal production. WVSMRA represents the surface coal mining industry and allied industries in West Virginia. On behalf of both organizations, I appreciate the opportunity to appear today to present their support for programs to develop and demonstrate enhanced technologies for the more efficient and environmentally sound use of coal for electric power generation.

The Department of Energy estimates that coal constitutes over 80 percent of our domestic energy reserve. Our national energy policy, developed to a large degree in this committee over the tumultuous decade of the '70's, is premised upon the increased utilization of domestic resources, as coal, for energy production. For that goal to be met, increased emphasis must be placed on developing pre-combustion, combustion, and post-combustion technologies through the commercial demonstration stage which permit coal use for power generation with reduced emissions. Through development and implementation of enhanced technologies for the more efficient and environmentally inert use of coal, coal will continue to provide low cost energy for America's homes and factories for the forseeable future. This course of action will work to simultaneously pursue and achieve both our nation's environmental and energy policies while providing for national security and fostering economic growth through a reliable source of low cost energy.

However, while the United States has enough economically recoverable coal to make our nation energy self-sufficient, we lack the technical knowledge to burn coal cleanly and efficiently. Continuation of this technical deficiency is ill-advised. The deficiency can be addressed through a joint coordinated effort of the public and private sector.

The legislative proposals pending before the subcommittee would provide such a comprehensive framework for development and demonstration of technology for expanded coal utilization. Through the increased use of coal as an energy feedstock for power generation and industrial applications, less plentiful fossil fuels as oil and natural gas will be available for their preferred use as a petrochemical feedstock, a residential heating fuel, and small scale industrial uses.

As reflected in the current controversy regarding the impact of coal combustion on acidification of waters in sensitive regions of the United States and Canada, the expanded use of coal as a primary energy feedstock is constrained by its environmental acceptability.

For coal utilization to increase and the goal of energy independence to be achieved, increased emphasis must be placed on research which demonstrates that coal can be used in a more efficient and environmentally acceptable manner. In the face of this acknowledged necesity, it is incongruous that over the past four years the Department of Energy's request for coal research and development funding decreased from approximately $800 million for FY 81 to $100 million for FY 84.

While we are encouraged by the proposed increase in funding for coal research and development in the Administration's proposed budget for FY 85, the underlying philosophy and budget proposals still reflect

THE VIEW THAT THE APPROPRIATE FEDERAL ROLE IS ONLY IN BASIC RESEARCH AND THAT DEVELOPMENT OF TECHNOLOGIES TO THE COMMERCIAL APPLICATION LEVEL SHOULD BE PERFORMED BY THE PRIVATE SECTOR. WHILE THIS PHILOSOPHY MAY BE APPROPRIATE FOR SOME INDUSTRIES, IT IS NOT APPROPRIATE FOR THE POWER GENERATION INDUSTRY, AND, IF PURSUED, WILL FRUSTRATE THE NATIONAL ENERGY PLAN.

THIS OBSERVATION IS PREMISED UPON THE COMPOSITION OF THE COAL INDUSTRY AND THE REGULATORY CLIMATE WITHIN WHICH THE UTILITY INDUSTRIES OPERATE.

THE COAL INDUSTRY IS HIGHLY COMPETITIVE, CLOSE TO 3000 COAL PRODUCERS COMPETE FOR COAL'S CURRENT SHARE OF THE POWER GENERATION MARKET, APPROXIMATELY 51 PERCENT. AS AN INTENSELY PRICE COMPETITIVE INDUSTRY, RESEARCH DOLLARS IN THE COAL INDUSTRY ARE SPENT ON MORE EFFICIENT MINING AND RECLAMATION TECHNOLOGIES WHICH WILL REDUCE THE COST OF COAL WHILE STILL MEETING THE REGULATORY REQUIREMENTS OF APPLICABLE ENVIRONMENTAL LAWS. FOR THOSE COMPANIES CAPABLE OF FINANCING SUCH RESEARCH, THE BENEFITS OF REDUCED PRODUCTION AND RECLAMATION COSTS WILL ACCRUE TO THE SHAREHOLDERS OF THE COMPANY. RESEARCH INTO COAL COMBUSTION TECHNOLOGIES WILL YIELD NO BENEFIT TO THE OWNERS OF A COAL COMPANY.

THE MORE LOGICAL INDUSTRY TO PERFORM COAL COMBUSTION RESEARCH IS THE ELECTRIC POWER INDUSTRY -- THE PRIMARY USER OF COAL IN THE UNITED STATES. THE INDUSTRY DOES PERFORM RESEARCH THROUGH JOINT EFFORTS AS THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI). INDIVIDUAL UTILITIES, HOWEVER, ARE CONSTRAINED FROM MAKING ANY SUBSTANTIVE CAPITAL OUTLAYS FOR RESEARCH AND DEMONSTRATION OF TECHNOLOGIES BY THE REGULATORY CLIMATE IN WHICH THEY OPERATE. STATE PUBLIC UTILITIES COMMISSIONS (PUC'S) ARE NOT

GENERALLY WILLING TO PERMIT UTILITIES TO MAKE THE CAPITAL OUTLAYS NECESSARY TO DEMONSTRATE TECHNOLOGY THAT HAS NOT BEEN PROVEN AT THE COMMERCIAL SCALE LEVEL. JUST AS PUC'S DO NOT WANT RATE PAYERS TO FINANCE TECHNOLOGY DEMONSTRATION, UTILITY SHAREHOLDERS ARE NOT EAGER TO FINANCE THE LARGE COST OF SUCH DEMONSTRATIONS.

GIVEN THIS BACKGROUND, IT IS CLEAR THAT THE ADMINISTRATION'S EXPECTATION OF THE PRIVATE SECTOR BRINGING PROMISING TECHNOLOGIES TO THE COMMERCIAL DEMONSTRATION STAGE IS NOT GROUNDED IN THE ECONOMIC REALITIES FACING THE COAL AND UTILITY INDUSTRIES. THE NATIONAL COAL, SCIENCE, TECHNOLOGY, AND ENGINEERING DEVELOPMENT ACT, INTRODUCED BY THE DEMOCRATIC LEADER, SENATOR BYRD, PROVIDES A COMPREHENSIVE PROGRAM TO ADDRESS THIS DILEMMA.

S. 1925 BASICALLY MAINTAINS THE EXISTING FEDERAL ROLE IN COAL SCIENCE RESEARCH AND PROCESS SCIENCE AND TECHNOLOGY AREAS BY FOCUSING RESEARCH ON THE USE OF COAL IN A MORE EFFICIENT AND ENVIRONMENTALLY ACCEPTABLE MANNER WITH EMPHASIS ON THE MOST COST EFFECTIVE TECHNOLOGIES TO ACCOMPLISH THOSE OBJECTIVES. THIS PRIMARY FOCUS IS EXPANDED UNDER S.1925 TO ADDRESS THE PROBLEMS ASSOCIATED WITH THE DISPOSAL OR USE OF THE BY-PRODUCTS OF VARIOUS PROCESSES. SENATOR BYRD'S BILL WOULD THEN ADDRESS THE DILEMMA OUTLINED ABOVE THROUGH AN ENGINEERING DEVELOPMENT PROGRAM DIRECTED AT ESTABLISHING PROOF-OF-CONCEPT FOR PROCESSES AND COAL UTILIZATION SYSTEMS AT A SCALE LARGE ENOUGH TO PERMIT READY COMMERCIALIZATION BY THE PRIVATE SECTOR.

A SIMILAR PROGRAM WAS ESTABLISHED AND CONTINUES TO FACILITATE THE USE OF NUCLEAR ENERGY FOR POWER GENERATION. THE PROGRAM BEGAN WITH THE DEPARTMENT OF DEFENSE'S CONSTRUCTION OF THE 80 MEGAWATT SHIPPINSPORT'S NUCLEAR POWER FACILITY IN THE LATE 1940'S. IT IS DOUBTFUL THAT THE NUCLEAR POWER INDUSTRY WOULD HAVE DEVELOPED WITHOUT THAT ASSISTANCE.

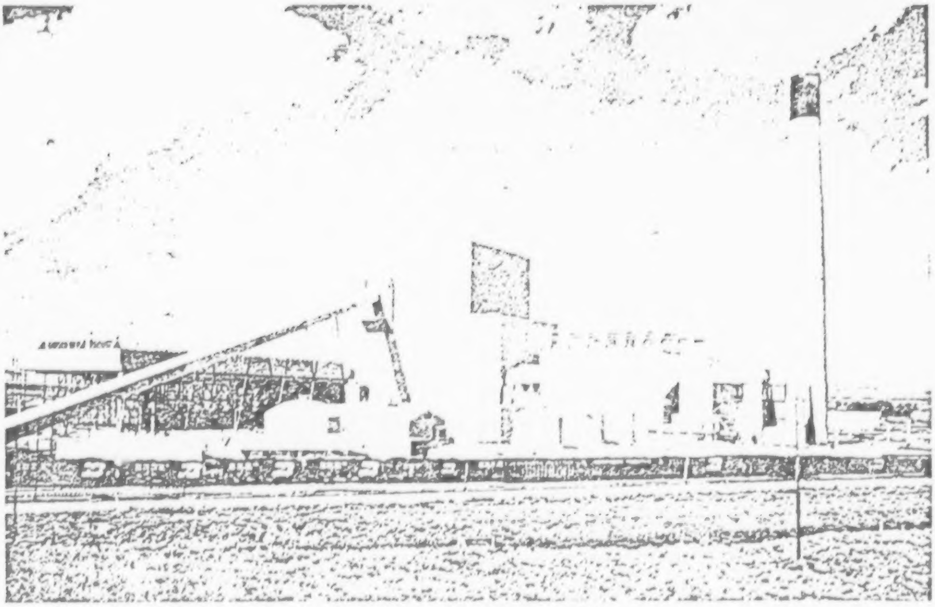
IN ORDER TO ASSURE THAT FEDERAL DOLLARS ARE NOT EXPENDED FOR PROCESSES WHICH ARE NOT COMMERCIALLY VIABLE, S. 1925'S ENGINEERING DEVELOPMENT PROGRAM IS PREMISED UPON ATTRACTING PRIVATE SECTOR PARTICIPATION BY PROVIDING FOR COST-SHARING BETWEEN THE FEDERAL GOVERNMENT AND NON-FEDERAL PARTICIPANTS. THE COMBINATION OF FEDERAL RESEARCH AND FINANCIAL PARTICIPATION WITH THE MARKET TEST OF NON-FEDERAL COST SHARING WILL HELP TO ASSURE DEVELOPMENT TO THE PROOF-OF-CONCEPT STAGE OF ONLY THOSE TECHNOLOGIES WITH POTENTIAL FOR COMMERCIAL APPLICATION IN THE UTILITY INDUSTRY.

S. 1278, INTRODUCED BY SENATOR MELCHER, WOULD AUTHORIZE A PROOF-OF-CONCEPT DEMONSTRATION OF A SIGNIFICANT TECHNOLOGICAL ADVANCE IN COAL COMBUSTION, MAGNETOHYDRODYNAMICS (MHD). BY DEMONSTRATING THE CONCEPT AT AN EXISTING POWERPLANT, S. 1278 WOULD PROVIDE ALL THE RELIABILITY AND OPERATIONAL TESTING OF DATA NEEDED FOR COMMERCIAL EVALUATION OF MHD TECHNOLOGY AT A FRACTION OF THE COST OF A NEW, FULL-SCALE DEMONSTRATION PLANT. S. 1278, AS S. 1925 WOULD INTEGRATE NON-FEDERAL COST SHARING THROUGH DEMONSTRATION AT AN EXISTING POWER-PLANT.

BOTH BILLS PROMISE THE DEVELOPMENT OF TECHNOLOGIES THAT WILL INCREASE FUEL CONVERSION EFFICIENCY AND REDUCE EMISSIONS IN COAL COMBUSTION. AS SUCH, THEY WILL PROMOTE AND ACCELERATE ACHIEVEMENT THE GOALS OF ENERGY INDEPENDENCE AND A CLEANER ENVIRONMENT. WHEN VIEWED IN LIGHT OF OUR NATION'S BALANCE OF PAYMENT DEFICIT FOR OIL IMPORTS AND ASSOCIATED RAMIFICATIONS AND THE STAGGERING COSTS OF VARIOUS EMISSION CONTROL PROPOSALS, THE COST OF THE LEGISLATION BEFORE THE

SUBCOMMITTEE IS NEGLIGABLE.

WE URGE THE SUBCOMMITTEE TO RECOMMEND EXPEDITIOUS COMMITTEE MARKUP AND SENATE PASSAGE OF THESE MEASURES.



A typical coal-fired electric power plant, this one in Gillette, Wyoming. (Photo, EPRI)

Coal Technology: Cleaning Up A Dirty Fuel

By Karen J. Hoffman
LandMARC Editor

During testimony on coal research before two House Science and Technology Subcommittees, two interesting statistics were revealed: first, that the 12th Congressional District of Pennsylvania has recoverable coal reserves with an oil energy equivalent of 33 billion barrels, more than the oil in Iraq and more than the oil in all of South America; and second, while fully 90 percent of energy used in the United States is obtained through combustion of fossil fuels (coal, oil and natural gas), there is little technological or scientific understanding of the coal combustion process.

Obviously, coal is abundant. Economically mineable reserves in 31 states are estimated by the federal government at 473 billion tons, more than 40 percent of the world's supply. And clearly, the future of coal use in this country is inextricable from energy consumption and the growth of electricity generation as a source of that energy. Close to 55 percent of America's total electric generation comes from coal, utilities accounting for 84 percent of total United States coal consumption. (Coal also holds an 8.5 percent share of industrial boiler fuel market.) That symbiotic relationship is expected to continue as oil and natural gas supplies remain expensive and unreliable.

But, a curious conclusion can be drawn from the statistics given to the House Science subcommittees: while the United States has enough recoverable coal to make this nation energy self-sufficient, we lack the technical know-how to burn coal cleanly and efficiently. A continuation of that technical deficiency bodes ill for both coal producing and coal using industries.

"Coal is a dirty, nasty, inconsistent fuel and it burns in a highly polluting, corroding and unreliable manner," Dan Hartley, director of Combustion Sciences at Sandia National Laboratories, told the Energy Development and Applications Subcommittee. "These problems have to be solved. This is not a matter of choice but an absolute necessity."

Coal contains sulfur and nitrogen, which when emitted as oxides during the combustion process contribute to the formation of acidic deposition. As national concern over the potential problems of acid deposition grow, so do outcries for control of utility emissions. Currently, such control can be achieved in one of two ways: by utilities switching to cleaner fuels or by installing scrubbers on smoke stacks to clean emissions. The first option will hurt producers of high-sulfur coal and disrupt the economies of coal producing regions. The second option, because it is so costly (by the early 1980s, there were 87 scrubbers in operation in the United States at an installation cost of $4 billion and operation cost of $1.7 billion a year), will hurt everyone.

There is, however, a third option—the development and commercialization of new technologies that will enable utility and industrial boilers to more cleanly and efficiently burn all grades of coal and the development of new fuels through conversion of coal to other energy forms such as coal-oil and coal-water mixtures or methanol gas.

These technologies fall into four categories: 1) precombustion, or the cleaning of coal before use to remove as much pyritic sulfur as possible (perhaps up to 95 percent); 2) combustion, during which as much as 90 percent of the coal's sulfur content can be removed inside the combustor, eliminating the need for smoke stack scrubbers; 3) post-combustion, which includes new techniques in flue gas desulfurization (scrubbing), and 4) advanced technologies, which may circumvent the coal combustion process altogether.

According to Hartley, "The embryonic U.S. coal research effort, just as it is about to enter its infancy, is situated precariously near an abyss into which it may well disappear because of massive cuts in the DOE Fossil Energy Research Program." In 1981, the Department of Energy (DOE), the primary federal arm for coal research and development (R&D), had a $1 billion budget for coal related research. For fiscal year 1984, the figure has been trimmed to $226.7 million.

Whether research and development of coal technologies will proceed at a fast enough pace to meet the nation's growing energy needs, whether or not the utility industry is financially sound enough to invest in new power plants utilizing advanced technology, and who, in fact, will finance R&D programs are questions currently troubling Congress as it seeks to assure energy independence for our nation.

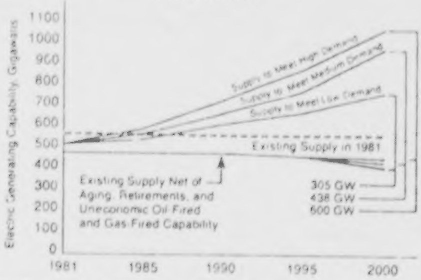
THE NEED FOR COAL RESEARCH

The United States emerged as the world's leading industrial nation through its use of coal. Combustion of coal has fueled everything from pot bellied stoves for heating homes to railroad locomotives to multi-megawatt electric utilities. Despite this storied history of coal use, according to Dr. Richard Traeger, manager of Sandia's Geo Energy Department, "We really don't understand enough about coal to anticipate how different coals will process in our combustors or reactors."

The critical implications of Traeger's comment were anticipated in 1978 when, reacting to the economic disruptions caused by the oil embargos of the early and mid-1970s, Congress passed the Fuel Use Act which prohibited the construction of major oil- and gas-fired power plants. In effect, Congress was alerting the world that the United States hence forth would rely on its huge coal resources, which constitute nearly 90 percent of our entire energy reserves. The Fuel Use Act forced increased direct use of coal and requires fuel substitution where coal or coal-derived fuels can displace oil and natural gas.

According to Hartley, that emphasis on coal use has created "severe environmental, efficiency, safety and reliability demands on equipment manufacturers and designers—demands that cannot be met without an understanding of the fundamental characteristics of coal combustion."

ELECTRIC SUPPLY REQUIRED TO MEET DIFFERENT LEVELS OF ELECTRIC DEMAND, COMPARED WITH EXISTING SUPPLY NET OF AGING, RETIREMENTS, UNECONOMIC CAPABILITY



High Demand = 4 Percent Annual Growth in Peak Load
Medium Demand = 3 Percent Annual Growth in Peak Load
Low Demand = 2 Percent Annual Growth in Peak Load

Coal use research and development in the 60s and 70s focused on cleaning emissions through flue gas desulfurization, the costly "scrubber" technology. Said Hartley during a subcommittee hearing, "The standard phrase then was, 'We already know how to burn coal.' The trouble is, nobody would recognize seriously that we don't know how to burn it cleanly, efficiently and reliably."

According to the 1983 National Energy Policy Plan, coal, nuclear and renewable energy (falling water, solar, wind and biomass) will be relied on to provide fuel for growing electricity demand, which is projected at an annual growth rate of from 2 to 4 percent. DOE figures show that at a medium growth rate (3 percent), 438 additional gigawatts (1 gigawatt equals 1,000 megawatts) of generating capacity will be needed by 2000. In 1981, DOE noted, the U.S. had 572 gigawatts generating capacity. Despite current reserve margins of 30 to 35 percent (at least 20 percent is required to assure a reliable source of electricity), current supply plans will be deficient nationally on an economic basis by 1989. The North American Electric Reliability Council (NERC) reports that of 152 gigawatts expected to be in service by 1990, only 107 are sufficiently underway now to be completed on time. More than 200 delays or cancellations of new coal-fired or nuclear facilities were announced in 1980–81 alone, delays that will cause consumers to pay $20 billion more for electricity (in 1982 dollars) over the rest of the century.

"Many people are aware that the nation has managed to sustain economic growth since the oil embargo of 1973 without corresponding increases in total energy consumption," DOE said of the nation's conservation efforts in fuel use. "But, they fail to realize that electricity demand has continued to increase since then. This is a critical misunderstanding."

Equally critical is public misunderstanding of the difficulties facing the utility industry in its attempts to meet this growing demand. Whether or not technologies that will assure clean, efficient use of coal are developed on a commercial basis, it is questionable if electric utilities will be financially able to gamble on the availability of that technology.

THE DUBIETY IN PLANNING POWER FACILITIES

According to the Electric Power Research Institute (EPRI), it takes a decade or more to plan, site, license, design and construct a new power plant. That means that work on facilities to generate the 438 gigawatts anticipated to be needed by the 1990s must begin now. But, according to Fred Denny, director of engineering for the Edison Electric Institute (EEI), the current financial plight of the utility industry may well preclude its constructing plants capable of utilizing new technologies that may become commercial by the time plants now in the planning stage actually go on-line.

"The decision to commit to a plant is a major decision," Denny said. "We operate on extremely long lead times and we are facing questionable availability of financing and technological uncertainties. It is impossible," he emphasized, "to build plants around technology that hasn't reached maturity."

Contributing to the long lead time are siting difficulties (fewer sites are available, said Denny, and there is more and more public opposition), fuel cost projections, swings in the economy and uncertainties in labor and material availability.

The other major unknown complicating a utility's decision to build a new power plant is the chameleonic nature of federal regulations. Current air quality standards may change by the time a plant is constructed, making obsolete the plant's coal-cleaning designs. Equally important is the lack of assurance that public utility commissions (PUCs) will allow a utility to bring in a rate base to cover costs. "You may have demonstrated need and economic viability for a new plant," said EEI's Richard Braatz, vice president of finance, "but years from now new commission members may decide they're not bound by the earlier commission's decision and they disallow your recovery costs."

Said Braatz, "Our financial health has to be turned around before many companies will be in a position to take the financial risk associated with new technology."

Financial risk also affects new technology research and development.

According to Hartley, by the late 1970s the DOE, under its billion dollar Fossil Energy Research Program, had succeeded in putting into motion a "well-planned and broadly based program of research in coal combustion and conversion. Ironically," he added, "this only happened after nearly 10 years of spending billions of our dollars on demonstration plants that have gone nowhere." He fears that current federal budget cuts may condemn DOE's recent achievements to a similar no-return conclusion.

THE NEED FOR COORDINATED EFFORTS

Hartley said it is essential that researchers from industry, universities, national laboratories and energy technology centers work together on the problems stymieing efficient coal use. But, he warned House members, the infrastructure does not exist within industry to conduct such coordinated research. "Only the federal government has the capability of undertaking a long-term R&D task of the magnitude needed to assure future coal use," he said.

The need for government coordination of new technology development becomes apparent when one considers the complexities involved in conducting the various phases of R&D: basic research, applied research, proof-of-concept, process development and commercialization. According to Rep. Nick Rahall (D-WV), who introduced in the House last October a 5-year, $775-million R&D legislation package authored and earlier introduced in the Senate by West Virginia's Robert Byrd, the federal government "rarely will take it (R&D) beyond the proof-of-process stage, expecting the private sector to undertake process development prior to commercialization."

The Reagan Administration's policy to let market forces encourage the private sector to support basic coal science and technology will not produce the multi-discipline, multi-institutional sustained work required to develop commercially applicable technologies, said Peter Solomon, president of Advanced Fuel Research, Inc. "On the basis of short term market considerations industry has, in the past, supported research relevant to their particular use of coal," he told the Energy Development subcommittee. "However, basic science will benefit all coal processes, including combustion, liquefaction and gasification.

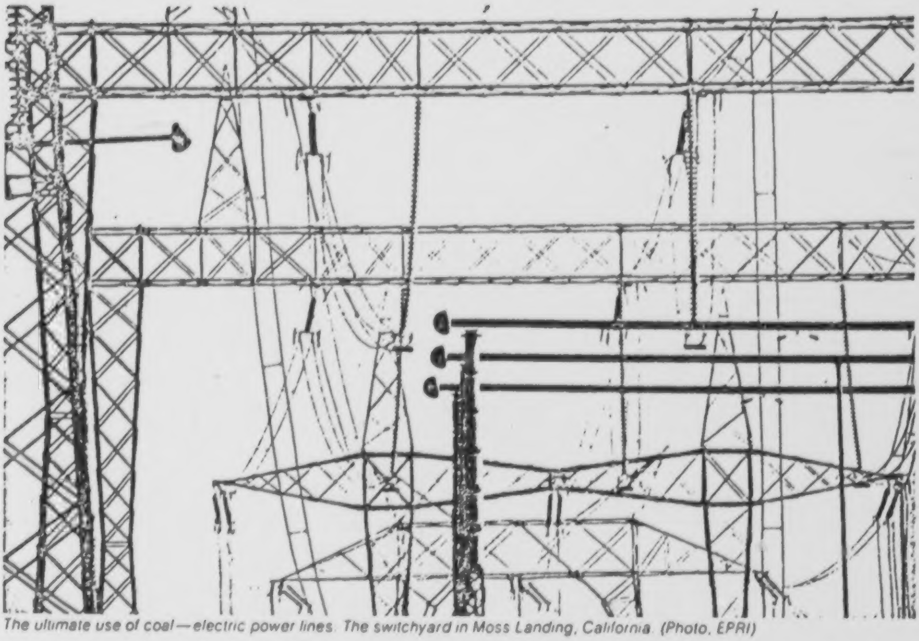
"While no single industry can justify the total support of such coal science," he continued, "the integrated payoff to the nation can well justify its (the government's) support."

The coal industry faces the same financial dilemma in promoting coal research. Said Daniel Gerkin, president of the Mining and Reclamation Council of America, "Because coal production is such a highly competitive industry, research dollars will go toward efficient mining and reclamation technologies in order to meet the stiff price competition in the coal industry. Funding coal combustion research, while the coal industry fully agrees that it is imperative to the future clean and efficient use of coal," Gerkin continued, "cannot be justified by coal companies because such research will not enhance a company's market position or yield increased return to its stockholders."

Solomon said the task of defining coal science is "formidable" and to make progress it is necessary to utilize fully the scientific resources in the country. "This means using the ideas, scientific expertise and facilities of all appropriate disciplines," he said. "It further requires free dissemination of research results and freedom from the requirement for immediate product-oriented results."

Gerkin noted that not even the utility industry, even though it has pooled its research efforts in EPRI, is in a position to finance new technology research to the commercialization stage. "In order to demonstrate the applicability of new technologies, a utility must be assured of its ability to recover the cost through the rate base, something that generally has not been permitted by the state PUCs," he said.

"No state is going to permit one of its regulated utilities to take the risk of demonstrating commercialization of a new technology. As a consequence," Gerkin emphasized, "the only funding source available for such substantial investment in commercial scale demonstration of technologies is the federal government."



The ultimate use of coal—electric power lines. The switchyard in Moss Landing, California. (Photo, EPRI)

Even with federal coordination of R&D efforts, a significant barrier exists to increased private sector-federal government cooperation in coal science research: technology and data rights. Dr. Gerald Petersen, general manager of the Allis-Chalmers Coal Gas Corporation, told House members that DOE rights and data clauses and patent policy are significant deterrents to companies attempting to develop a leadership position in their industry.

"The standard DOE rights and data clauses put background technology, developed under private sector funding by the contractor, at risk if that background technology in any way becomes involved in the conduct of the federal government contract," he said. "And, the DOE patent policy reserves for the Department the right to march in and seize background patents if they feel it is in the best interest of the nation.

"Consequently," said Peterson, "the firm with a substantial leadership position in an industry has the most to lose in accepting these contract terms and conditions. The end result frequently is a 'no-bid' response to R&D proposal solicitations from the private firms with the best ability to perform the subject effort."

TOWARD A SOLUTION

Sen. Robert Byrd (D-WV) in introducing legislation for a 5-year, $775-million coal research and development plan last October, told his colleagues that when Congress established the Office of Coal Research in 1961, "we acknowledged the significance of coal to the nation's energy future. We also recognized at that time the need for research and development in coal technologies. My bill," he said, "builds upon and accelerates activities in DOE's coal program and refocuses and integrates such efforts and concentrates resources for achievement of specific objectives within five years."

The National Coal Science, Technology and Engineering Development Act of 1983, authored by Byrd and later introduced in the House by Rahall, while not specifically addressing Petersen's concerns about DOE's rights and data clauses, does in the engineering development section stipulate that the program "be structured and implemented such that there are sufficient incentives to attract private sector participation."

The Act outlines a comprehensive program that integrates government, university and private sector research and development efforts with the goal of achieving commercially proven coal-cleaning, combustion and coal conversion technologies within five years after enactment of the measure.

In Part II of its series on coal technology, LandMARC will review the history and current status of research and development efforts by the government and the private sector, and discuss several of the most promising technologies in the pre-combustion, combustion and post-combustion phases of coal use. Part III will address the future of coal use in power generation: how will it fare with potential increased competition from synthetic fuels and nuclear generation? And will development of coal-water and coal-oil mixtures facilitate the conversion to coal use of plants currently fueled by oil or natural gas?

Is Coal Technology On Again?

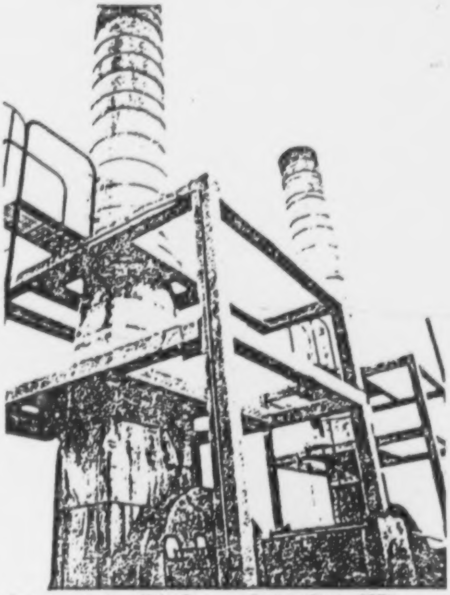
By Karen Hoffman
LandMARC Editor

(Second in a Series)

American research and develoment (R&D) in coal sciences and coal use technology has been compared by some to the Chinese Cultural Revolution, with one major exception. While China's so-called "Cultural Revolution," in which all research and education projects were halted, spanned a single 10-year period, Americans put the halters on coal R&D every five years or so.

"The Chinese Cultural Revolution is a disaster from which it will take them generations to recover," Dr. Charles Hosler, dean of the College of Earth and Mineral Science at Pennsylvania State University, told a House Science and Technology subcommittee. "We do the same thing about every five years," he continued. "We have about a five-year cycle of this off-again-on-again business in research. We suffer a great deal in this society not from lack of a long-range plan, but from lack of a sustained effort in our research programs."

A partial listing of prominent coal R&D players—the Bureau of Mines Bruceton Laboratory in Pittsburgh, an experimental coal mine and coal analysis facility opened in 1910 and which later evolved into DOE's Pittsburgh Energy Technology Center; the Synthetic Fuels Act of 1944, which sadly led to no synfuels production; the Office of Coal Research, started in 1961; the Energy Research and Development Administration (ERDA), started in 1975; and the Department of Energy (DOE), started in 1977—and their combined results ("We have not produced one BTU out of the ERDA and DOE programs," said John Sudbury, vice president of Conoco's Coal Research Division) is testament to that lack of a sustained effort.


Scrubber stacks at TVA's Shawnee Station (Photo, EPRI)

When one considers that the length of time required to open a new coal mine or to construct a new power plant exceeds any electoral term in American government, be it a Representative, a Senator or a President, such a start-stop-start again schedule is somewhat easier to comprehend, if not accept. With new administrations come new concerns. And the coal industry—producers, users and researchers—are concerned about the Reagan Administration's tenor toward coal research and development.

In one respect, research in coal sciences is "on again," but perhaps from the wrong perspective. The spectre of acid rain has pushed the need for scientific understanding of the byproducts of coal combustion, sulfur dioxide (SO_2) and nitrogen oxide (NO_x), to the forefront as Congress battles with the Reagan Administration over acid rain control programs. Some members of Congress propose multi-billion-dollars-a-year programs to control SO_2 and NO_x emissions as a method of reducing acid deposition while the Administration is holding fast to funding research to more scientifically define the acid rain problem.

What concerns the coal industry and a large portion of the research community is that both Congress and the Administration are concerned with cleaning up emissions, not preventing them. Members of Congress want to impose an extremely costly flue gas scrubber retrofit rerequirement on existing coal-fired power plants to control emissions. But, the best way to control SO_2 and NO_x, researchers contend, is to prevent those noxious gases from forming in the first place. And the way to do that is to develop cleaner, more efficient methods of burning coal.

"The money Congress would allocate to a retrofit program, or that the Reagan Administration would allocate to studying the causes and effects of acid deposition would be more effectively spent developing technologies to ensure the clean use of coal," said Daniel Gerkin, president of the Mining and Reclamation Council of America (MARC).

That is unlikely to happen, however, because coal research and development is "off-again" from the funding standpoint. And, as one disgruntled scientist told a House Energy subcommittee, "Without funds, even the best scientists can make little progress."

R&D FUNDING PROBLEMS

Nearly everyone agrees that coal R&D requires a trilateral effort among industry, the government and the universities. There is less agreement on who should pay for what and what, in fact, should be funded. Do you set a funding ceiling and then develop a research program to fit under that ceiling, or do you outline the R&D program and then come up with enough funds to carry it through? Should R&D be aimed at goal achievement ("Build me a commercially available limestone injection multistage burner by 1986!") or aimed at building a base of solid scientific knowledge ("So that's how that blasted sulfur attaches itself to the coal ")? Should government force private industry to assume the financial burden of R&D by enforcing stiffer environmental regulations? Or should the federal government regard enhanced coal technologies as a commitment to the energy defense of the nation and fund R&D through the demonstration stage before expecting private industry to take over?

Those are just a few of the questions with which government officials and industry and university scientists are grappling in attempting to determine the most efficient method of developing economically viable coal burning technologies.

Coal technologies generally fall into three categories: 1) precombustion, or cleaning coal to remove as much sulfur as possible (perhaps as much as 95 percent of pyritic sulfur, or 30 to 45 percent of the total sulfur content), 2) combustion, during which as much as 90 percent of the coal's sulfur content can be removed inside the boiler, and, if combustion temperatures are kept low enough, nitrogen oxide formation is reduced, and 3) advanced technologies, which may circumvent the coal combustion process altogether. Research is ongoing in flue gas desulfurization (scrubbing), but that method of emissions control is expensive (almost $2 billion in operating costs each year for those scrubbers currently on line) and is regarded as a choice of last resort.

According to the *Special Analysis of the Budget of the United States Government FY 1985*, released with the full budget presented by President Reagan to Congress on February 1, 1984, the total federal funding in the coming fiscal year for research and development, including R&D facilities, is estimated at $53 billion, an increase of $6 billion, or 14 percent, over the estimated 1984 level of $47 billion. The *Special Analysis* states that the federal government supports research and development "for national defense and to support environmental regulation; and, to assist in meeting broad national needs, particularly where the private sector lacks incentives for adequate investments to assure long-term economic growth and continued improvement in the quality of life."

There are those in the scientific community and the coal industry who argue that United States energy independence, the stated goal of this Administration, which depends heavily on the environmentally sound increased use of coal, is 1) a matter of national defense, and, 2) is beyond the financial capabilities of the private sector. The budget, however, proposes continued reductions in nearer term R&D programs that are not considered federal responsibility, "and thus should be left to the states or the private sector for appropriate investments, including nearer term technology development programs of the Department of Energy."

Among those nearer term R&D programs is coal technology. The bulk of the $4.9 billion allocated to DOE for research and development is the $2 billion earmarked for the National Defense Program, which primarily supports the continued development and testing of nuclear weapons and development of improved technologies for monitoring nuclear weapons treaties and safeguarding nuclear materials. By comparison, funding for the conduct of fossil energy (coal, oil and natural gas) related R&D and associated facilities is $273 million in 1985, a decrease of $57 million. The budget figures specifically for coal research for the past three fiscal years show a steady decline: $252 million in 1983, $246 million estimated for this year and but $187 million proposed for 1985.

The effect of such deep and immediate budget cuts has been devastating. John S. Mead, director of the Illinois Energy Resources Commission (IERC), warned members of Congress about the potentially disruptive effect of the withdrawal of federal funding in testimony before House Science and Technology Committee members late in 1982. He said, "In pruning the fossil energy R&D budget, the administration has placed many research institutions in a position from which they may not recover, even with subsequent increases in state and private support. One of our real fears is that the crucial transition from major federal funding to private support for research, especially for the later (demonstration) phases, is just not going to occur because the cutoff of federal funds was so abrupt and so deep. The momentum," he said, "is lost."

The Reagan Administration defends its potentially crippling R&D budget cuts on the grounds that it "sought to eliminate from federal programs those large-scale demonstration and commercialization activities that are more appropriately designed and carried out by the private sector," as stated in the Secretary of Energy's 1983 Annual Report to Congress. As a result, the report said, federal energy expenditures for R&D have been decreased while funds for basic research have been increased.

The concept of allowing the market to dictate what is economically viable and what is not is philosophically sound, especially when the nation is facing a multibillion-dollar deficit and hence must tighten its belt. The problem is that the free market philosophy does not work in energy research and development. "Energy is not a free market business," said MARC's Gerkin. "It's one thing for General Motors to conduct market research on a new automobile because most people drive cars. It's quite another for a utility to product test a fluidized bed combustor in a $200-million, 160-megawatt power plant."

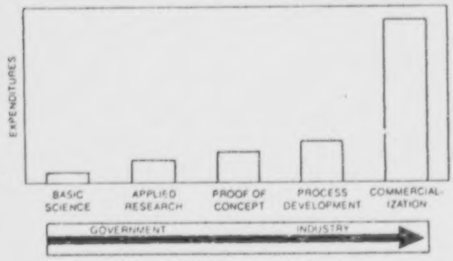
One of the managing directors of the Tennessee Valley Authority (TVA), which with the Electric Power Research Institute (EPRI), Duke Power Company and DOE currently is operating a 20-megawatt fluidized bed combustion pilot plant at Paducah, Kentucky, likened the Reagan Administration's R&D policy with "moving the ball to the ten-yard line and punting. Their theory is, if it's deep in the R stage of R&D the government should fund it. But, as soon as it approaches commercial success the government falls out and that leaves the gap between the ten-yard line and the goal. Everyone knows that is the toughest terrain to overcome. The risks that remain are too great for private companies to assume."

WHAT IS BEING RESEARCHED, AND HOW?

Why is research in coal use technology so contentious when America, in all likelihood, will become dependent for energy on its 473 billion estimated tons of economically recoverable reserves? One answer, from Dr. Robert Kessler of Avco Everett Research Lab, is the "Catch-22" of coal R&D. "Past programs have been unduly influenced by the energy crisis climate of the past decade," he said. "Programs were aimed at producing short-term results and therefore made use of existing technologies and processes or minor improvements to them." In order even to demonstrate these improvements, however, required large and costly demonstration plants. The results in most cases, said Kessler, were "marginal."

"What happened was that really new technologies based on the results of the past ten or fifteen years received little attention because the benefits from them would come too far in the future to meet immediate needs," he continued. "So a sort of Catch-22 situation developed in which promising new technologies would receive no support until results were shown, and, of course, no results could be obtained without support."

One example offered during Congressional hearings was the fluidized bed combustion project at the Great Lakes Training Station north of Chicago. The state of Illinois contributed funds and a private corporation, Combustion Engineering, pumped millions of dollars into the project. Said IERC's Mead, "The failure of the federal government to see that project through has really harmed the development effort in fluidized beds. Perhaps this was not going to be as successful as other fluidized bed programs, but this was one that had actually gotten off the ground and was in the testing phase. Unfortunately, the boiler stands idle today and is sort of a bitter reminder to Illinois that the federal government has not been a very good partner."



The Illinois complaints are because government pulled out during the proof-of-process stage, when new technologies get their first practical test, the stage at which the federal government believes free market forces should take over. Most coal and utility industry representatives and researchers agree that government aid is needed through the demonstration stage, the final 10 yards as the TVA spokesman called it, when technologies are proven to be commercially viable.

The research needs for government financial assistance are myriad. Dr. Charles Kolb, vice president Applied Science Division, Aerodyne Research, Inc., gave an outline to the House Energy Development and Applications Subcommittee. "Successful design and utilization of advanced systems requires a firm base of research, not only in chemical kinetics and fluid mechanics of coal combustion, but in materials research to design high temperature, reliable components, in basic corrosion research to identify the chemistry and physics of materials failure; in diagnostic and control development to allow real-time measurements of combustion characteristics and continuous adjustments of combustion conditions, and in hot gas steam homogeneous and heterogeneous processes to allow quantification and removal of corrosive, erosive, or environmentally dangerous combustion exhaust species."

Just what are the promising new technologies that demand such huge financial commitments and prompt such debate over how to best develop them?

THE CURRENT STATUS OF COAL R&D

A typical pulverized coal particle is about the size of face powder. It's lifetime in a boiler lasts just a few seconds, a long time on a chemistry clock. Two processes consume the particle: the first lasts a few milliseconds to a tenth of a second in which the volatile gases come off the coal, igniting and burning, forming nitrogen and sulfur oxides. The second phase takes longer, perhaps a couple of seconds during which the char burns out and the ash is released from the coal. The ash melts and fuses, which can clog and corrode the boiler system. "Very little of this is understood in any detail at all," Dr. Dan Hartley, director of Combustion Sciences at Sandia National Laboratory, told House Energy Committee members. The amount of SO_2, NO_x and ash created during combustion changes with the purity of the coal introduced into the boiler. The cleaner the coal (the less sulfur and extraneous particulate matter) the cleaner it will burn. Unfortunately, the BTU (or heat) producing level of coal will closely associated with its sulfur content.

PRE-COMBUSTION TECHNOLOGIES

It is estimated that less than 25 percent of all coal consumed by the utility industry each year is cleaned, and that generally only to a small degree, the rest is burned run-of-mine, complete with extraneous ash, sulfur and other impurities. Sulfur in coal is found in two forms: inorganically bound, or pyritic sulfur, and organically bound. Although the latter is difficult to remove, pyritic sulfur can be effectively removed by physical means such as crushing and washing the coal.

Physical coal cleaning is a proven technology. Coal has a lower specific gravity than the impurities (including sulfur) associated with it. Thus, by placing coal in a solution with a specific gravity between the two causes the coal to float and the impurities to sink. The coal then is removed and dried. Innovations in physical coal cleaning include froth flotation units, multiple screening devices and magnetic separators.

Physical coal cleaning is commercially available, and it can be done by coal companies at the mine site, thus cutting transportation costs. According to EPRI, roughly one carload of impurities can be removed from four carloads of coal by physical coal cleaning. Most coal-washing facilities are large, handling more than 14,000 tons per day, enough for a 1,000 megawatt power plant. Clean coal improves coal quality, boiler performance and leaves less ash residue for disposal.

While physical coal cleaning can remove as much as 90 percent of the pyritic sulfur, as much as 65 to 80 percent of the total sulfur content in coal is organically bound and can be removed only by chemical processes. Chemical coal cleaning processes are in an early stage of development and are considerably more expensive than physical cleaning.

Chemical coal cleaning (CCC) uses more sophisticated chemical processes to remove sulfur, including the tiniest pyritic particles that cannot be removed physically, as well as some organically bound sulfur. Total sulfur removal, pyritic and organic, ranges between 50 and 90 percent. The goal of new chemical cleaning technologies is to achieve at least 90 percent removal, thereby offering util-

(Photo, EPRI)

ities a cost-effective alternative to smokestack scrubbers.

As a result of the Reagan Administration's emphasis on privately funded R&D, only two chemical coal cleaning methods, GE microwave and TRW gravimelt, both of which promise to desulfurize coal to a degree that will eliminate the need for scrubbers, have been funded by DOE. Both have been tested on high-sulfur Eastern and Midwestern coals and have achieved 80 percent total sulfur reductions.

Chemical desulfurization techniques work best on coal that also has been physically cleaned and crushed to fine size to remove course pyrite particles that actually inhibit chemical reactions. The coal then is mixed into slurry form with water or a water/chemical reagent solution. The mixture and additional chemical reagents are fed into a reactor vessel which is sealed, heated and/or pressurized, forcing much of the sulfur into solution with the liquid reagents. The coal emerges from the reactor vessel impregnated with the sulfur-containing reagent fluid which is removed by washing with water. The coal then is caked and dried. The cleaning water can be recycled and the reagent liquid further processed to remove the sulfur. The reagent also then can be recycled.

Most CCC research began before 1977 when emission standards for utility boilers were less stringent than now. Government projects (Ames Laboratory, Jet Propulsion Laboratory and Pittsburgh Mining Technology Center) and corporation projects (GE, TRW, ARCO, Kennecott and others) have developed processes, designed plants and estimated problems, benefits and costs. However, only a few developers are ready for pilot plant projects, which are estimated to cost well over $10 million.

For CCC to become a viable commercial technology, it must achieve 90 percent sulfur reduction, experts contend. But lack of sufficient theoretical knowledge about the molecular structure of coal is a key factor limiting the sulfur removal capacity of chemical coal cleaning. According to John R. Sellars, vice president and general manager of the Energy Technology Division of TRW, the Gravimelt process is nearing the proof-of-concept stage, "with adequate funding. If the federal government's role as partner in R&D is not maintained," he told a House Energy subcommittee, "many of these promising coal technologies now being evaluated in the laboratory will never reach the marketplace . . . and centers of excellence in this field will be forfeited."

COMBUSTION TECHNOLOGIES

Combustion in a coal-fired burner usually takes place at 2500 to 3000F, with excess air pumped in as needed to ensure complete combustion of all the carbon. Unfortunately, this simple process creates environmentally unpalatable results: sulfur and nitrogen in the coal combine with oxygen to produce sulfur dioxide (SO_2) and nitrogen oxide, particulates (ash and other noncombustibles) are emitted with the flue gases; hard ash, which can foul the boiler, also is formed.

Two of the most promising combustion technologies, both designed to remove sulfur, nitrogen and ash from the coal in the boiler, and both retrofittable to existing power plants, are the fluidized bed combustion and limestone injection multiplestage burner (LIMB) technologies.

Atmospheric Fluidized Bed Combustion

Atmospheric fluidized bed combustion (AFBC) offers utilities an opportunity to use abundant, less costly, lower-quality coals not used in conventional power plants due to environmental standards. Because the capture of sulfur is inherent during the combustion process, coal not fully burned can be reintroduced into the boiler, thus assuring full use of the coal while maintaining environmental integrity. Also, because the combustion temperature is lower in AFBC (1400 to 1700F, roughly one-half the temperature of conventional coal-fired boilers) production and release of nitrogen oxide is significantly less.

During the AFBC process, coal is burned in a bed of limestone particles suspended by air fed into the bottom of the boiler at atmospheric pressure. The resulting coal-limestone mixture bubbles like a fluid. The sulfur is chemically captured by the limestone and leaves the boiler in the ash, rather than escaping in the flue gases. This eliminates the need for costly flue gas scrubbing for pollution control, improves overall efficiency and reduces capital costs. Also, due to the lower operating temperature, the AFBC boiler design is less dependent on fuel and fuel-ash characteristics, allowing power suppliers to burn a wider variety of fuel types without significant performance deterioration. Studies indicate that the ash byproduct may have useful applications as an agricultural supplement, road base filler or cement additive.

The origin of fluidized bed combustion generally is traced to the Winkler gas generator developed in Germany in the 1920s. Fluidized beds have been used in many chemical processes involving a reaction between a solid and a gas or between two gases where a solid catalyst is used to promote the reaction. It has been widely used in the steel industry for ore roasting. During the postwar period, experiments began in the generation of steam using hard-to-burn materials in a fluidized bed. It soon became obvious that anything combustible would burn in fluidized beds and in the 1950s they were being commercially used for the incineration of municipal sewage sludge.

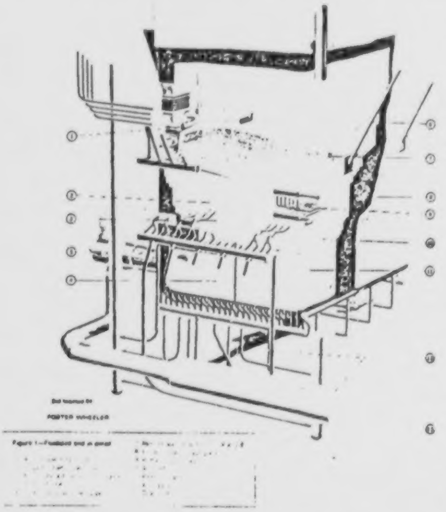
Among current testing operations for electricity generation are four being conducted by the Foster Wheeler

Corp. Monongahela Power Co. in Rivesville, West Virginia. Georgetown (Washington, D.C.) University, DOE Morgantown (West Virginia) Energy Technology Center and the city of Wilkes-Barre, Pennsylvania.

And TVA, in cooperation with Duke Power, EPRI and DOE, has a $68-million, 20-megawatt facility using a Babcock and Wilcox fluidized bed combustor on line at its Shawnee Steam Station in Paducah, Tennessee. The plant is using high-sulfur bituminous coal and may test alternate fuels, including lignite, according to Dr. Arnold Manaker, project manager. Since shake-down began in May 1982, the plant has consumed 26,043 tons of coal and 11,298 tons of limestone in 4,439 hours of operation.

"Preliminary cost estimates indicate that in the East the capital cost of an AFBC plant is 10 to 15 percent less than a conventional coal-fired plant with a scrubber," Manaker said. "In the West, the capital cost advantage is projected to be 15 to 20 percent." He added that operating costs in the East are estimated to be 5 to 10 percent less and in the West 7 to 12 percent less than operating costs under current systems.

A utility-scale demonstration facility, which will replace an existing pulverized coal-fired boiler with an AFBC boiler, is currently under construction at Shawnee. The 160-megawatt facility has a projected cost of $220 million with TVA providing $40 million, EPRI $75 million, Duke Power and the Commonwealth of Kentucky $10 million each and DOE $30 million. The remaining $55 million is being solicited from vendors, states, foreign nations, coal producers, railroads and utilities.



"There is a limit to what a ratepayer in the Tennessee Valley should pay to subsidize the rest of the nation," a TVA director said. "It is important there be federal funding for a first-of-a-kind demonstration that will allow this nation to take abundant, dirty, high-sulfur coal to back out our dependence on imported oil." The test program on the 160-megawatt facility is scheduled to begin in 1989, with commercial operation testing scheduled to begin in 1993, almost a decade hence.

Limestone Injection Multistage Burner

Limestone injection multistage burner (LIMB) is considered a "particularly promising control process" by the Congressional Research Service because it has the potential to reduce both SO_2 and NO_x emissions by 50 to 70 percent and is designed to be retrofitted to existing facilities. Such a retrofit system is currently operating in West Germany. Furthermore, LIMB is projected to be inexpensive to install and operate with capital costs projected to be between one-seventh and one-tenth the cost of flue gas desulfurization. The Environmental Protection Agency (EPA) has actively supported LIMB technology development, but recent budget cuts have drastically reduced funding for a demonstration effort.

LIMB consists of injecting a dry, pulverized calcium-based material (such as lime or limestone) directly into the furnace cavity of a coal-fired burner. On entering the furnace, the sorbent material decomposes into lime which reacts in suspension with SO_2 to form a solid calcium sulfate. The calcium sulfate and unreacted sorbent particles then are removed with the flyash collected in the particulate control device. The process is entirely dry and utilizes conventional equipment for the storage, handling and injection of the sorbent material.

The LIMB concept developed in the early 1960s as an alternative to reducing SO_2 emissions without the complicated and costly scrubber systems, according to Kurt Yeager, vice president of the Coal Combustion Systems Division of EPRI. "The low and variable removal efficiencies of these early systems essentially discredited the approach and by the early 1970s wet scrubber systems became the focus of SO_2 development."

Yeager said the causes of poor SO_2 removal capability of the early LIMB systems (injecting the sorbent into the boiler when the temperature was too high causing deactivation of the lime, and injecting the sorbent at too high a level in the boiler, causing inadequate mixing with SO_2-bearing combustion products) are being rectified.

The process development and commercialization schedule begins with laboratory development, ending late this year, followed by prototype verification testing of a small (50-100 megawatt) utility boiler in 1986 and the first large (400+ megawatt) utility boiler demonstration beginning in 1988. Yeager said the LIMB system can reduce boiler performance and increase maintenance, and that based on an SO_2 removal of only 50 percent, the cost per ton would range from $650 to $1,000. "Thus the relatively low SO_2 removal efficiency and high limestone requirement may tend to offset the capital cost advantage over scrubbers," he said. But LIMB can be easily and inexpensively (compared with scrubbers) retrofitted to existing boilers and that makes it a very attractive SO_2, NO_x control system.

ADVANCED TECHNOLOGIES

Several other emerging coal technologies have the potential to control SO_2 and NO_x emissions, among them the integrated gasifier/gas turbine combined cycle, the integrated gasifier/fuel cell combined cycle, magnetohydrodynamics (MHD), and electron-beam irradiation. These systems still are several years away from commercial use.

but have the potential to burn fossil fuels more efficiently and emit lower levels of SO_2 and NO_x than systems currently in use. A DOE spokesman briefly outlined these systems in testimony before the House Subcommittee on Energy Development and Applications.

Integrated Gasifier/Gas Turbine Combined Cycle

This technology is typified by the 100-megawatt Cool Water power plant now under construction at Daggett, California, and is potentially retrofittable. When completed in 1984, the commercial-scale demonstration project will integrate the gasification of coal with the generation of electricity by a combination of gas and steam turbines. The coal first is gasified and then the clean gas is burned in a combustion turbine. Exhaust emissions of particulate matter, SO_2 and NO_x are expected to be well below federal new source performance standards for new power plants.

In this system, sulfur is effectively removed in the gas cleaning process. Fuel bound nitrogen comes off in the form of ammonia, which is washed out or which can be catalytically decomposed in a hot gas cleanup process. Combustion modification can be used to control the formation of NO_x from the air. However, while the system is expected to be efficient on controlling NO_x, it is less effective on SO_2 emissions.

Magnetohydrodynamics (MHD)

The MHD concept offers the potential for reducing SO_2 and NO_x emissions without the use of post-combustion cleanup technologies. SO_2 is captured by potassium seed required to render the hot combustion gases electrically conductive. The sulfur then is recovered in the form of sulfuric acid or elemental sulfur. NO_x formation is reduced by combustion modifications such as temperature controls.

Like other advanced coal-fired otions, MHD also offers improved thermal efficiencies, perhaps as high as 50 percent. The electricity is generated directly from the thermal energy, bypassing the transfer of heat to mechanical energy. While current electric utility plants operate at 33 to 40 percent efficiency, MHD systems could operate at efficiencies of 50 percent. However, there are several technical uncertainties that must be addressed before this technology can be moved into commercial development. Little is known about water pollution problems from the leaching of potassium salts from the resultant coal ash and refuse from the potassium seed regeneration wastes. Likewise, there may be air pollution problems from potassium salt release from particulate control equipment.

TRW began MHD coal combustor research in 1975 and in 1979 constructed a fossil energy test site to accommodate MHD. TRW stated in late 1982 that with continued federal support it planned to deliver a 50-megawatt MHD combustor to the government facility in Montana for completed testing in 1984.

OF WHAT USE THESE NEW TECHNOLOGIES?

These are just a few of the technologies being developed to ensure the clean use of coal. Without a doubt, there are as many individuals concerned with utilizing coal to produce energy as there are individuals mining coal. The question hanging over all this work and research is whether the federal government will commit its resources to pushing these fledgling technologies into commercial reality or will continue, instead, to pledge those resources to studying the adverse effect of using dirty coal—acid rain.

"The paradox concerning acid rain abatement is partially a result of a narrow view of potentially available technologies for controlling SO_2 and NO_x emissions from stationary sources," said the Congressional Research Service report on *Mitigating Acid Rain With Technology*. Technologies are available now or will be in a very few years which can significantly reduce SO_2 and NO_x emissions without significantly reducing the efficiency of utility plants or creating dislocations in the coal market.

Whether or not that approach will be pursued is what Congress and the Administration must decide.

Overview of Control Technologies

Control Technology	Reduction Efficiencies	Revenue Requirements (Mills/Kwh)	Stage of Development
Sulfur Dioxide			
Fuel Switching	30-90%	0-7	In Use
Physical Coal Cleaning	5-40%	1-5	In Use
Chemical Coal Cleaning	60-85%		Emerging
Wet Flue Gas Desulfurization	70-95%	10-17	In Use
Dry Flue Gas Desulfurization	40-90%	9-15	In Use
Limestone Injection Multistage Burner	50-90%		Emerging
Fluidized Bed Combustion	<90%	Emerging	

In Part III of its series on coal technology, LandMARC will address the future of coal use in power generation. How will coal fare with possible increased competition from synthetic and renewable fuels, such as solar power and biomass, and nuclear generation? Will development of coal-water and coal-oil mixtures facilitate the conversion to coal use of plants currently fueled by oil or natural gas? □

OSM Rules

continued from page 21

REMINING (9/16/83)

The final rules treat remining operations the same as all other operations for permitting purposes. However, remining operations may be excepted from the AOC restoration requirements and total highwall elimination upon demonstration to the RA that the volume of all reasonably available spoil is insufficient to backfill the reaffected or enlarged highwall completely. The operator will be responsible for eliminating the highwall to the maximum extent technically practical. All spoil generated by the remining operation and any other reasonably available spoil within the permit area must be used to backfill the area. Any highwall remnant must be stable and not hazardous to public health and safety or the environment. □

Senator DOMENICI. Thank you very much, Mr. Keating.

I gather then that what you're saying, Mr. Keating, with reference to cost-sharing, you're suggesting that the nature of the coal mining business is significantly different than say the gas producers, who do indeed participate significantly in Gas Research Institute work.

Mr. KEATING. I would say gas—OK, the price of coal as I said, basically, the gas industry is on a long-term basis—the country is running out of gas. It is not running out of coal. Therefore, our profit margins are dictated by very intense competitive pressures. And if the price gets out of line at all, you can bring on a new mine. You have to discover a gas field, you don't have to discover where the coal is.

Senator DOMENICI. Well, I don't know that that really makes any difference. Are you really saying there isn't enough profit in coal for them to contribute. Is that it? I mean, I don't think it makes any difference that you don't have to bring a mine on and you do have to produce a new gas well in terms of who contributes to R&D.

Mr. KEATING. The coal industry has a rate of return that is substantially lower than the gas industry, or the whole oil and gas industry; and, therefore, could not afford long-term projects.

Senator DOMENICI. Well, you know, I thought they were spending some money in long-term R&D, the coal companies.

You said they're only doing that with reference to mine safety and——

Mr. KEATING. That's where the major funding goes.

Senator DOMENICI. I tell you what I would like to have because I don't know—maybe Senator Ford could tell me about it, but maybe for the record, Carl, could you put in the record the 25 largest producers of coal in the United States and what percentage of the coal they produce?

Mr. BAGGE. Certainly.

[Pause.]

Mr. BAGGE. If it isn't presumptuous, Mr. Chairman, I don't want to take the burden of that question, but——

Senator DOMENICI. Of course.

Mr. BAGGE. It seems to me that in my mind to compare the regulated utility sector of our economy, my associate here from EPRI has a very convenient way of funding the work of EPRI, the research arm of the electric utility industry through the mechanism of the rate structure.

Our colleagues in the gas industry with GRI have a similar means of generating sources of income for research.

As an old regulator of these two industries, I can tell you that I was the guy over for 6 years at FPC screaming that something ought to be done before GRI or EPRI was even thought of.

Now, to apply that to the 3,000 economic entities that we call the Nation's coal industry, which is exceedingly competitive and doesn't have the neat and convenient and orderly mechanism that the regulated utility sectors, both electricity and gas have, and to make comparisons with them and the 3,000 economic industries that we call the coal industry is grossly unfair.

If the two largest that you have asked me to identify begin contributing—some of them have, I might say. In fact, Peabody Coal, I just recall, have made a significant contribution here recently to this effort.

But if those 10 producers, for example, were to make a massive commitment of whatever income they—if they generated any income, and that's highly questionable in my industry in the last several years, but assuming they did, they would be placed at an economic disadvantage with respect to the 2,950 other economic entities who are competing for precisely the same market and trying to keep their costs, as my colleague from Grafton says, down so they can have some margin of profit.

That's our basic problem. We have been through and up and down the hill on this one in the past, but I think in my mind that's the fundamental distinction. You can't compare the coal industry with the massive oil producers or the gas producers or, indeed, the regulated sectors of our economy. It doesn't fit.

Senator DOMENICI. I have a few questions for each of you, but in the interest of time, I'm going to give them to you for response at your convenience and yield to Senator Ford.

Senator FORD. Thank you, Mr. Chairman.

I might say that what my good friend, Mr. Jones has stated, is that the shortfall of research and development in our State has somehow been made up by long-term—or at least 4-year commitment by private enterprise.

Isn't that right, Mr. Jones?

Mr. JONES. That's right.

Senator FORD. Of 400,000 per year by several firms each of the next 3 years—or is it——

Mr. JONES. Four years.

Senator FORD. Four years.

And the contribution that's being made comes from some of the fossil resource groups into our ability to try to do some more research at our lab.

Mr. Chairman, I would like to read a paragraph from today's Inside Energy, and then submit the rest of it for the record, if I may.

> Energy Secretary Donald Hodel in a move some observers read as DOE's willingness to fill a perceived gap in fossil energy R&D, told a Pennsylvania Congressman last week that he was, quote, "strongly interested," end of quote, in a proposed $100-million increase in coal-related R&D. A DOE spokesman said Hodel telephoned Representative Doug Walgren early last week to congratulate him after the House Energy Subcommittee on Fossil and Synthetic Fuels adopted Walgren's endorsement to boost fiscal year 1985 and 1986 R&D funds by a $100 million to finance coal utilization and environmental engineering demonstrations—"demonstrations," that goes beyond pilot, doesn't it?—on a cost-shared basis with industry. Hodel promised the DOE official said, quote, "to review the amendment fully and, if appropriate, to go to the Office of Management and Budget with a request for the funds."

So, Mr. Chairman, I would like to include the balance of this statement as referred to that into the record.

Senator DOMENICI. It will be made part of the record, Senator.

[The article follows:]

Hodel Plans To Review $100-Million Coal-Technology Demonstration Program

Energy Secretary Donald Hodel, in a move some observers read as DOE's willingness to fill a perceived gap in fossil-energy r&d, told a Pennsylvania congressman last week that he was "strongly interested" in a proposed $100-million increase in coal-related r&d, a DOE spokesperson said. Hodel telephone Rep. Doug Walgren D-Pa., early last week to congratulate him after the House Energy subcommittee on fossil and synthetic fuels adopted Walgren's amendment to boost FY-85 and FY-86 r&d funds by $100 million to finance coal-utilization and environmental-engineering demonstrations on a cost-shared basis with industry. Hodel promise, the DOE official said, "to review the amendment fully and, if appropriate, to go to the Office of Management and Budget" with a request for the funds.

Walgren's amendment was adopted as part of legislation authorizing $5.4 billion for DOE's non-defense r&d and related programs in FY-85 and in FY-86 (H.R. 5048). The subcommittee completed its markup of the bill. It will now be considered by the full Energy and Commerce Committee, but not until after natural-gas legislation has been moved, according to a subcommittee staffer.

Walgren according to a spokesman, took the Hodel call as a signal that DOE was ready to support his proposal, which Walgren had discussed earlier with William Vaughan, DOE assistant secretary for fossil energy. The incentive for DOE support is a cost-sharing provision that would be mandated by the amendment. It would, for the first time, codify the cost-sharing principle embraced by OMB as a condition for federal support of costly demonstration projects and pilot plants. An official in Vaughan's office said DOE "would like to see a policy of 50 percent or more" cost-sharing by industry in such projects. "Our experience is that cost-sharing brings projects in closer to schedule and closer to budget than those that don't have such provisions," the official said.

Walgren's national coal-engineering program would be administered by DOE's energy technology centers. Industry would be able to apply for assistance in the construction of semiworks, or demonstrations, of environmental-control engineering technologies and utilization technologies. The environmental technololgies eligible include:

Fine-coal preparation and cleaning, including chemical coal cleaning at a scale of not more than 500 tons/day;

Retrofits of oil boilers of not less than 100 megawatts capacity, using coal cleaned with various technologies;

Retrofits of oil boilers of less than 100 Mw capacity, using a coal-water mixture;

Advanced regenerable flue gas cleanup on existing coal-fired plants of between 20 Mw and 100 Mw;

Combined sulfur dioxide/nitrogen oxide removal from coal-fired plants of 20 Mw to 100 Mw; and

Advanced combustion modification for high nitrogen-oxide reduction on coal-fired plants of not less than 50 Mw.

Retrofit application of in-boiler sulfur control on existing coal-fired facilities of not less than 50 Mw in utilization technologies, assistance could be provided for any of the following:

Repowering application of combined-cycle coal gasification of 50 Mw to 100 Mw;

Coal-fueled gas turbine in second-generation combined-cycle systems of not less than 50 Mw;

Industrial-scale coal-fueled gas turbines suitable for cogeneration of not less than 5 Mw;

Integrated magnetohydrodynamics systems tests, including generators and downstream-steam plants with superconducting magnets;

Advanced direct coal liquefaction at a scale of 5 tons to 10 tons of coal per day; and

Advanced indirect coal liquefaction at a scale of 5 tons to 10 tons of coal per day.

DOE would also be charged under Walgren's amendment with preparing a five-year national coal engineering research plan that would point to opportunities for coal use in the residential, commercial, industrial and electric-utility sectors, with DOE plans for meeting such opportunities, priorities for achieving such objectives and the resources needed to complete such a plan. DOE would have to complete an annual report in FY-85 and FY-86 on the coal engineering program.

Senator Ford. And one question—and as he said, it's like preaching to the choir, but let me ask you, Commissioner Jones, where can Kentucky participate in the program as you envision it, where you say add the States as a partner, open up a new channel, how can Kentucky participate in this program as you envision it?

Mr. JONES. In virtually all phases of the program, because we're involved in basic coal science research which we support through our own research program at about—it has been 7½ million, it will probably be dropping to less than $5½ million with our budget cuts, all the way up to demonstration scale activity.

Now, we don't have the entire fleet of activities that the bill envisioned, but we are involved in several of those and have an interest in some that we don't.

We, of course, are participating with electric power research in the 160-megawatt fluid bed unit, as well as with TVA. So we cover—we're already doing things represented by the entire range of this bill. So we would see simply involving our base of support and allowing the Department of Energy to get more bang for their buck by putting our money together to pursue some of these things.

Senator FORD. So does your participation include engineering?

Mr. JONES. Not engineering, no.

Senator FORD. Not engineering. I'm afraid I might brag on him if I asked him anything more.

Senator DOMENICI. Senator, could I ask you if between you and Senator Melcher you could complete the hearings?

Senator FORD. I think Senator Melcher has already agreed to stay through the next panel. I have to go. I'm already late for another one. But I'm going to stay through this one.

Senator DOMENICI. I want to make one observation, if you both would permit me, before I leave, for the entire panel.

First of all, I hope you don't interpret anything I've said here today in terms of inquiring to mean that I'm opposed to increases in research and development money, and that I have some automatic philosophical fix that I know where to draw the line, that every demonstration shouldn't be done because that's somebody else's business not ours.

You on the panel know me, know that isn't me. I'm not that. What I am disturbed about is the fact that we cannot find a way in this Congress to fund research in an way that is meaningful to those that are doing research. And you're excited about this bill because you say it has continuity, it is a 5-year authorization.

Everyone that's submitting new legislation in the last 18 months or so is talking about 5 years, and saying, wouldn't it be great if we had continuity, and then support authorizing bills as if they in and of themselves supply the continuity. They don't.

And it's deplorable that we can't find a way to do that. But I would suggest that Senator Ford has an approach that is totally unrelated to this bill that will have more to do with continuity, and that's 2-year appropriation bills.

Maybe we ought to even find a way in research and development, Senator, to set some real goals and take less money and do it for 5 years.

I don't see how people can do research on the off-and-on spigot that we've got on a 1-year appropriation.

Now, having said that, you've got to remember that everybody in the business of using Federal money says the same thing. I mean those who are procuring military hardware in appropriations, they are rightfully saying you are insane to appropriate for fighter pilots every year. If you're going to buy 150, why don't you let somebody buy 150 like businessmen would and pay for them in a most economic way. We don't even do that.

So I think from time to time to pass bills that say this is a 5-year program is extremely healthy, but I urge that those of you who are familiar with these institutions understand that we need help in terms of the overall processes, not just this bill. We're about to strangle ourselves on appropriating and authorizing and budgeting and we don't even know where we're going half the time, because we can't swallow it all.

So I regret having used up the last 3 or 4 minutes here in the appearance that I'm telling some—lecturing anyone, but I think we let down everyone when we pass a 5-year authorization and they expect that we have 5-year commitment at a certain level, when it ain't really true.

I mean we might appropriate 1 year, as the Senator knows, and the next year cut it in half. Right? And that's not necessarily done with a great deal of wisdom and prudence, it's done——

Senator FORD. To try to get to that end figure.

Senator DOMENICI. Exactly.

Having said that, it's——

Senator FORD. Mr. Chairman, before you leave, let me say that we wouldn't be as far along in research and development in this area if it were not for you. I understand your dedication and concern, and I want you to know that I, for one, appreciate it.

It's been stated here this morning, I think during your absence, that if somehow what we're doing in this 1925, that if we—that $775 million, if we could just have a 1-percent increase in coal by the year 1990—in the use of coal, 1 percent increase, it would more than return the Federal Government the entire contribution in 1 year.

So I think we're going to have to bet on the come here, rather than look at it otherwise. And I think I have the feel that—well, my State, and I cannot speak for the rest of them, but that private enterprise is interested. They have done a selling job, or they have made contributions of their money. We're getting more bang for our dollar.

And you bring in this kind of interest and concern, we may find that the initiatives that we thought couldn't work, we found an innovative and inexpensive way to accomplish it.

And I thank you for your interest and your concern, and I don't take your 3 minutes as lecturing, it's just the fact of life. We need to change them, and you see that better than anybody.

Senator DOMENICI. The other thing that I would mention to the panelists in particular Carl, because of his relationships with various Senators from States that have a similar interest.

You know, Synthetic Fuels Corporation is another notion that we all supported, and we supported it because it was a way to apply a different technique to funding projects in this country that might have been very difficult if we had to appropriate every year.

I don't think they're marvelous or that they have done any extraordinary job, but basically I think we ought to give it a chance to get along, give it a chance to fund a few major projects. They're trying to put diverse energy research approaches to actual developmental levels, and I don't think we would ever get that done with the philosophy that we sometimes hear from the administration. I mean, if they aren't for demonstrations, how in the world would they built a full market-blown one with tax dollars?

Yet, we have succeeded to this point, as you know, Carl, in talking our President into leaving it there and to keeping it going. Well, we have got to do those kind of things, too.

I don't have any in my State. The Senator from Florida knows we don't have any projects that are going to fit that synthetic fuel. But I think we have got to keep that kind of thing going, too.

Mr. BAGGE. We agree completely with you, Senator. It's just that it's inherent in the nature of our system that when the gas lines are long, then we have a great commitment. And when the gas lines are gone, then we lose interest.

Senator DOMENICI. That's right.

Mr. BAGGE. But I couldn't agree with you more that we've got to keep our eye on the ball and have some sense of vision and continuity. And to the extent to which this bill provides—may I say—I'd like to identify my association with the comments of my good new friend here that I've just met on this occasion who works for a former director of mine, George Evans, the energy czar of the Commonwealth of Kentucky, who I'm told is a good friend of the doctor here. But I would like to identify, and to the extent to which the States have been excluded from the bill, it seems to me in my perception of the national labs is such, I would much rather have the State of Kentucky doing it than some of the national labs, or at least include them in the bill. I can say that, I think, without fear of being fired by my board of directors, when I want to embrace the Commonwealth of Kentucky's contribution to this dialog.

Senator FORD. Mr. Chairman, I want to say that Kentucky has really come a long way, Mr. Bagge has now embraced us. [Laughter.]

God bless you, Mr. Bagge.

Mr. BAGGE. God bless you.

Senator MELCHER. Before you all leave, I want to add to these recent pearls of wisdom by my colleagues here.

Commissioner Jones and Vice President Spencer, and Vice President Keathing, and my friend of the National Coal, Association, President Carl Bagge, I want to say that we've got the coal, we're going to use it more in the future to supply our energy needs. We haven't done too well right now or in the past, or the immediate past, but we shall do a lot better.

So to all of you, keep the faith. Coal is the faith. Thank you very much.

Mr. BAGGE. Thank you, Senator Melcher.

Senator DOMENICI. I wanted to just say to Carl, you may have acquired a new friend on your right, but if you talk too poorly of the national labs you'll lose this friend.

Mr. BAGGE. I'm not knocking them.

Senator DOMENICI. You just wanted a little flexibility.

Mr. BAGGE. That's it. You've got it.

Senator DOMENICI. Thank you very much.

Senator MELCHER [presiding]. We will call the next panel. Jack E. Katlic, senior vice president, fuel supply, American Electric Power Service Corp., from Ohio.

Joe McElwain, chairman of the Montana Power Co., of course, from Butte, MT.

William Podolny, vice president and general manager of fuel cell operations, United Technologies, from Connecticut.

William Irving, vice president, Charles T. Main, Inc., from Boston.

I think we're to hear from you first, Mr. Katlic.

STATEMENT OF JACK KATLIC, SENIOR VICE PRESIDENT, FUEL SUPPLY, AMERICAN ELECTRIC POWER SERVICE CORP., ON BEHALF OF THE AMERICAN MINING CONGRESS

Mr. KATLIC. Thank you, Senator.

I'm Jack Katlic, from the American Electric Power Service Corp. I'm here representing the American Mining Congress, which is a trade association, organized under the laws of the State of Colorado.

We represent producers of most of America's metals, coal, industrial and agricultural minerals, manufacturers of mining and mineral processing machinery, equipment and supplies, and engineering, consulting firms, and financial institutions that serve the mining industry. So there are interests here across the board.

At the risk of repeating many things that have been said already, Senator, I would ask that my prepared testimony be admitted for the committee's consideration.

I would like to then just be brief and talk on just a couple of principles.

As an ad hoc committee that our chairman formed because of his concern within the industry itself that this matter was not being properly address. And when I say "properly addressed," I mean successfully addressed.

I have heard all other statements this morning. Some of them deal with cost, some of them deal with profit. I would have to tell you that our opinion is that neither of those things apply to the problem of research with coal.

Coal is already the most economical fuel that can be used in this country. So there has to be another reason why it is not being used.

So the mission that we see with R&D, the mission has to be to make it environmentally acceptable. Now, obviously, to make it environmentally acceptable it must be also then economical that the citizen has to be able to afford what happens with it.

What happens with that then, that's where we identify with the program as presented under Senator Byrd's legislation.

We have some problems with the control functions. We believe that rather than the traditional DOE approach, we think it should be as the Synthetic Fuels Corporation approach.

We think the companies are well aware of what it takes that they need to make coal attractive and to make it efficient to use and in an environmentally acceptable fashion.

We believe the producer is well tuned to know how to meet that competitive situation.

We have some specific problems then in how the effort is attained and who runs it. If it's the traditional old programs, we don't think it's going to make any ground at all.

The funds are limited. But the Senator's bill, with some modification, addresses it very well. We would only caution that the timeframe may, in fact, not be long enough.

If several other things that are happening in the country to make the coal environmentally acceptable, as the Congress works on other legislation, that may well in turn preclude a short-leash on this existing R&D Program.

So we just want to exhibit our complete support. We have identified the sections that bother us in the bill.

I thank you for allowing us to testify.

[The prepared statement of Mr. Katlic follows:]

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Testimony of Jack Katlic
Senior Vice President-Fuel Supply
American Electric Power Service Corporation
and Chairman of the
American Mining Congress
Ad Hoc Task Force on
Coal Industry Research and Development

Before the

Subcommittee on Energy Research & Development
Senate Energy and Natural Resources Committee

on S. 1925

April 9, 1984

Good morning, Mr. Chairman. My name is Jack Katlic and I am senior vice president-fuel supply with American Electric Power Service Corporation, and chairman of the American Mining Congress Ad Hoc Task Force on Coal Industry Research and Development.

The American Mining Congress is a trade association organized under the laws of the State of Colorado. We represent producers of most of America's metals, coal, and industrial and agricultural minerals, manufacturers of mining and mineral processing machinery, equipment and supplies and engineering and consulting firms and financial institutions that serve the mining industry.

Our Ad Hoc Task Force was organized a little over a year ago to look into the matter of the coal industry's handling of technical research and development matters.

We welcome the opportunity to participate in this hearing and to provide you with our views on S. 1925, the bill introduced by Senator Robert C. Byrd last October.

First, let me say, Mr. Chairman, the American Mining Congress September 1983 Declaration of Policy provides:

> Dependence of the United States on politically and strategically insecure and price-volatile foreign energy supplies increases the nation's vulnerability to supply interruptions, undermines national security, hurts balance of payments and compromises foreign policy. In light of this, the present excess supply of foreign oil should not

be allowed to stall the drive to increase domestic availability of conventional energy and to develop alternative fuels.

The American Mining Congress endorses an energy program that will lead to greater national energy independence, albeit recognizing that energy development is a global concern. Development of additional supplies of domestic energy should have high priority in national policy-making, consonant with cost-efficient regulations designed to protect the environment and provide for worker health and safety.

AMC believes that efficient and competitive domestic production, including alternative fuels, and conservation of energy are in the national interest.

To remain competitive in international markets requires a constant effort in research and development for new technology and increased productivity. Research and development programs, which encourage the use of coal in an environmentally acceptable manner, will be beneficial to the nation.

As indicated in a February 6 letter to Senator Byrd from Ralph Bailey, chairman, American Mining Congress, we are pleased to support this legislation. It is an excellent approach for continuing and expanding the use of coal and we enthusiastically agree with the concept.

Mr. Chairman, I would like to make some general comments as expressed by our member companies, and offer specific comments on particular sections.

The overall goal of the three-part program contained in the bill, which is extremely commendable, may be unattainable as a practical matter with respect to the program management suggested, the large variety of projects for consideration, and the time period suggested for completion.

The suggested funding is like that used for synfuels by DOE. This type of funding is questionable. If industry finances the majority of the program, it will control the projects and complete them in timely fashion with usable results for the money spent. Since many participants would put only small amounts of money into projects, the projects would be government-run with a high level of DOE involvement. This approach would not provide clean-cut conclusions regarding the commercial viability of the candidate technology in reasonable time.

A better way of funding research would be similar to the SFC approach. Sufficient financial inducements are offered industry to take the technical risk to select technologies. The inducements could include financing options such as tax credits that would more likely stimulate industry interest. This approach has an added benefit of driving the poorer technology choices into the background, if reasonable criteria are used.

The research program money, as currently provided in the bill, would probably support the continuation of existing projects. If the legislation can focus the demonstration projects on a few high-priority areas, then the research program should fund long-range or more fundamental work with demonstrable connections to the demonstration projects. This does not preclude academic, fundamental research, but it should not include old projects reworked on paper to make them acceptable to some new funding source. If that proviso can be implemented, the research program will have enhanced value as part of the overall package.

If this proposed type of research and development is to succeed, we must pool the resources of the utilities and coal industries, as well as the research centers and academia, into one group and utilize their collective talents and energies toward the solution of problems in the fossil energy field, especially coal.

Our specific comments by section number follow:

Section 2(a)(10)--Fails to mention the national laboratories as in Section 3(a)(7)(b).

Section 5--We do not understand the distinction between coal science (Section 4) and process science (Section 5). Section 4 mixes science with process chemistry and Section 5 mixes science with engineering research. We recommend restricting Section 4 to coal science, Section 5 to process research and development and Section 6 to engineering research and development. These are clear distinctions that industry understands and can deal with.

Section 5(a)(2)--Exemplifies "coal mixtures", which is ambiguous. Coal-liquid mixtures is meant, or more specifically coal mixed with oil or water.

Section 5(a)(4)--Refers to "processes that are regenerable". Perhaps this is a semantic problem but processes are not regenerable--it's the ingredients going into processes that may be regenerated.

Section 5(a)(5)--Must have inadvertently omitted direct combustion of coal for electric power generation; should include it.

Section 6--The Engineering and Development Program. The purpose of this section is to establish proof of concept and produce developed processes at a scale large enough to permit ready commercialization by the private sector. We consider this a worthwhile section. It can fill the void that now exists between the DOE R7D program, which is pointed at basic and applied research with some work in proof of concept, and the Synfuels Corporation's efforts, which are aimed at assisting proven technologies to produce at commercial levels.

There currently exists no way to get from the proof-of-concept level to the commercialization level without the private sector's taking the monetary and technical risks involved. The preamble to S. 1925 emphasizes the importance of developing technology to ensure the continued utilization of coal in the event additional acid rain precursor controls are imposed. We call specific attention to the importance of timing.

Timing is essential because most of the major acid rain control bills require emission reductions in the 1990-1995 time frame. It typically takes at least three years to install a proven acid precursor control system on a major utility unit. This means that those new technologies which are going to be useable in time to meet the 1990-1995 compliance time frame must have been commercially demonstrated in the 1987-1992 time frame. It is important to note that if Congress enacts legislation with too tight a time frame (e.g. 1990) none of the emerging technologies addressed in S. 1925 will be available. Therefore, Congress could preempt the use of any new technology if it does not address compliance time frames in the late 1990s to allow commercialization of these technologies.

Under Section 6 of the bill, several technologies are described, but these technologies need to be reviewed and perhaps put in two categories--those technologies that are far enough along that they can be commercially demonstrated by 1992, and those that will be demonstrated beyond 1992. Three such technologies--advanced physical coal cleaning, limestone injection multistage burners, and pressurized and atmospheric fluidized bed combustion--should be encouraged under Section 6, with the remaining technologies supported as part of a second phase.

Section 6(a)--Makes no mention of diesel engines as in Section 5(a)(5)(D); we recommend that diesel engines be included.

The authorization levels set forth under Section 9 appear to be adequate to do the required job for the efforts described in the other sections, including Section 6. However, Section 6 may need to be broken out so that funding is provided for Phase I with additional funding to be added for Phase II. For example, the TVA EPRI Atmospheric Fluidized Bed Combustion Demonstration Unit alone is estimated to cost $220 million. Therefore, $500 million may not be adequate to fund both Phase I and Phase II of Section 6.

Section 7--We believe it is more appropriate to allocate funds for specific promising, ongoing research projects rather than follow the usual shotgun approach and we therefore suggest that a highly qualified nonpartisan committee selected from industry be authorized and appointed to serve as an advisory council to the Secretary of Energy in order to get valuable industry experience and judgment into the Five-Year Plan. The Advisory Council could select the most promising projects in conjunction with the overall planning.

We believe the role of the coal industry in the coal science research program outlined by the bill should be clearly outlined. Absent the involvement of industry in all phases of the program, we are concerned that funds will be allocated indiscriminately without significant industry feedback.

We would also call your attention to additional areas such as magnetohydrodynamics and coal liquefaction as providing additional markets to use the available unused coal production capacity now idle.

Mr. Chairman, we are most appreciative of the opportunity to appear before you. We offer the expertise of our membership in whatever way we can be of assistance to you in this worthwhile effort.

Senator MELCHER. Thank you very much, Mr. Katlic.

Joe, welcome to the committee, and we will be glad to have your testimony.

STATEMENT OF JOSEPH A. McELWAIN, CHAIRMAN OF THE BOARD, THE MONTANA POWER CO.

Mr. McELWAIN. Senator, thank you.

If I may have my written testimony put in the record, I will try to summarize the points I make with respect to your bill and with respect to magnetohydrodynamics.

We, in Montana, recognize what has been said here many times this morning; and, that is, coal is our greatest resource. Some 35 percent of the world's reserves of coal are located in the United States. Some 45 percent of that amount in the three States of Montana, Wyoming, and North Dakota.

We have in Montana some 120 million tons of coal reserves.

As you know, Montana Power Co. and its subsidiary Western Energy Co., are very deeply interested in the utilization and use of that coal. Western Energy is a coal producer that produces—will produce by the end of this decade some 24 billion—million tons of coal a year. And so it has a very great stake in the utilization of coal.

As a utility executive and manager, I just do not feel comfortable with being satisfied with 30 percent conversion factor of our coal resources. In other words, in the burning of the coal we are putting into the atmosphere in one form or another heat that is 70 percent waste.

And it seems to me incumbent upon us when there is a project or a process such as MHD out there, that we pursue the technicalities that are needed to improve that efficiency to a 45- to 55-percent utilization factor.

Your bill, and your support, as well as your predecessor's and Senator Mansfield have gone a long way in keeping this very promising technology in the forefront. And, in spite of your statement that we haven't made much progress in the last 5 years, I believe we have. I believe that your commitment and the commitment of Congress, particularly in the last 3 years to keep this program alive, have gone a long way to getting us where we are today, being ready to put together the components of the various factors involved in MHD into a pilot plant.

And I'm delighted to see that your perseverence and that of the others has brought around the administration to recognizing that this is something that we should proceed forward with.

My proposal in my testimony is a little different from Secretary Vaughan's approach, and yet not too far apart.

The point I try to make is that their proposal envisions a 12-megawatt bottoming unit, which is basically a conventional steam element, and 8 megawatts of—6 to 8 megawatts of MHD.

We have, as you know, located in Billings, MT, a gas-fired plant known as the Bird Plant that Montana Power Co. is willing to commit for R&D purposes totally, that plant. So that you wouldn't have to be spending the dollars to make the 12 megawatts bottoming unit. And that by utilizing that plant, you can upgrade the amount of MHD capability that's attached with for approximately the same number of dollars up into the area that the experts and the studies that have been made indicate of about a 20-megawatt electric size for MHD.

And then utilizing that plant to a great extent, you are putting all your dollars into the MHD components of research and development.

And I would submit that that would save some dollars and would represent a substantial commitment on the part of private industry to moving this process forward.

I'm delighted to see that there is a recognition of the environmental capabilities of going forward with this process.

I think one that has not been mentioned is the great contribution, if this is an economically feasible project, to transportation problems in this country. Because if you can get 55 percent utilization out of a ton of coal, it's going to cut down the needs of transporting that coal by a like amount.

And also, I think it represents good conservation.

The one other thing that I think I would like to suggest to the Congress—and I know multiyear financing always is a problem, but I believe if you're going to ask private enterprise to be a part of a long-term project and to contribute to it, you do need to give them some assurances that the program is going to be there the next year. And that there should be some vehicle and mechanism to know that a year from now their part of it's going down the drain because the Congress has changed its mind. And I think that's the important part of some kind of an authorization.

The last thing I would like to suggest; as you know, Senator, we, in Montana, have had several discussions in years past with the Japanese with respect to possible joint venturing of some of this technology.

They had shown great interest in it until we started cutting it totally out of our budget from the administration standpoint. And I think that anything that moves this forward should authorize our Government to again contact the Japanese, show them that we are again interested in an meaningful pilot program, and I believe that they will renew their interest and possibly be a joint venture partner in this process.

I appreciate very much the opportunity to present my views on this subject matter.

[The prepared statement of Mr. McElwain follows:]

Testimony of Joseph A. McElwain,
Chairman of the Board, The Montana Power Company

before the

Senate Energy and Natural Resources
Subcommittee on Energy Research and Development

April 9, 1984

My name is Joseph A. McElwain. I am chairman of the board of the Montana Power Company. Montana Power Company is an energy company which serves as an electric and gas utility to the western two-thirds of Montana. In terms of the area served, the Montana Power Company is the second largest operating utility in the United States. We also have major coal mining operations in Montana, Wyoming and Texas that are under Montana Power Company's wholly-owned subsidiary, Western Energy Company. Western Energy, last year, mined approximately ten million tons of coal and by the late 1980's will be mining approximately twenty-four million tons of coal a year in the three states it currently operates in.

I am deeply appreciative of the opportunity you have afforded me to testify in favor of S. 1278 which contains a comprehensive, multi-year coal-fired magnetohydrodynamics (MHD) technology development program and results in a meaningful "proof-of-concept" facility.

Montana Power Company and Western Energy Company have been early pioneers of the conversion of coal to energy through the MHD process.

As an electric utility which relies upon coal for its major base load, we are strongly interested in the efficient utilization of our coal resources.

Since 1973 when we in the United States got the signal of our vulnerability to dependence upon foreign sources of energy during the Arab embargo, the Montana Power Company has been a strong advocate of internalizing our energy capability through the greater utilization of our vast coal resources. The

United States possesses over 35% of the known coal reserves of the world, some 450 billion tons. The states of Montana, Wyoming and North Dakota possess approximately 45% of that coal reserve, with Montana having approximately 120 billion tons.

If we are to truly attack the problem of energy vulnerability, we must do everything possible to utilize these vast coal reserves.

It is for this reason that we in Montana have become great advocates of the MHD conversion process. As a utility executive, I simply cannot be satisfied with the present conversion factor of coal to electricity of approximately 30 to 35% efficiency. This is particularly true when there is a technology such as MHD which offers an ability to increase that efficiency to 45 to 55%. The commercialization of this process, in my judgment, represents one of the greatest contributions that can be made to efficient utilization of our coal resources, as well as making good conservation sense. In addition, it would also contribute greatly to the capability of transporting coal to its place of use because every ton of coal shipped, if MHD is commercialized, would render 50 to 75% more energy than it currently does, cutting down transportation costs and volumes substantially.

MHD meets environmental standards and goals, which could contribute greatly to solving our acid rain problems in the future.

MHD is a relatively simple conversion process which moves a hot conductive gas through a strong magnetic field which then causes current to flow in the gas. There are no moving parts which should allow the process to run for sustained periods of time. MHD has the highest potential efficiency of all the new coal-burning technologies; its combustion process inherently controls SO_x and NO_x. The impacts of burning coal 50% more efficiently have tremendous benefits in reducing related environmental impacts through less mining, less transportation, less effluents. There are no technological breakthroughs required to proceed with this promising conversion process. We are at the point where we need to prove its efficiency, economics and commercialization of scale. With all this potential and the possibility of lower cost electricity, I believe MHD warrants a definitive multi-year pilot program at adequate funding to progress toward commercialization at an early date.

As you are well aware, we have substantial problems to overcome before nuclear power becomes a continuing source of supply for our increased energy needs. This leaves our great coal reserve as the one reliable source of internally generated energy.

It is clear that coal must assume an increasing part of our national fuel mix. In 1974, coal accounted for about 44% of the energy utilities employed to produce electricity. In 1980, that figure had grown by only 6 percentage points -- to only 50% -- while the consumption of electricity had leaped 19%.

Looking just a few years into the future, the best forecasts indicate the demand for electricity will escalate 90% by the turn of the century because electricity is a versatile form of energy that can serve many needs. Coal could and should be used to generate more than 2/3 of our total electricity, assuming attractive economics and superior technology.

Yet without MHD or some unforeseen other technology, coal cannot be expected to assume its destiny in our energy mix. Only with the massive gains in efficiency, economics and environmental control offered by MHD can coal play its assigned part in the shift from primary reliance on shrinking oil suppliers to our relatively abundant coal reserve. Prolonging the life of our coal supply through the efficiencies of MHD suggests that we should follow a course that will bring about expeditious application of the promising technology.

Outside our country, there are active research and development programs for MHD in the Soviet Union, Poland, Yugoslavia, India, China, Netherlands, Australia and Japan. The Japanese, in addition to their own program, have expressed an active interest in possible participation with the United States in development of MHD. I predict that if we do not pursue MHD research, we will one day be buying this technology from other nations. However, today we are the leaders in coal burning MHD technology and in just a few years its viability can be proven.

The utilities are more interested today than ever before and rightfully so, for MHD is the only technology that has been meeting its milestones successfully. The dollars spent have brought significant advances in recent years in areas which at one time were considered show stoppers. The current status of MHD development is:

1) Channel life - has gone from seconds to minutes to 1300 hours testing and an extrapolated life of 8000 hours.

2) A 4800°F coal combustor has been successfully developed and tested by TRW at the 20 MW_t level and 90% slag rejection; with testing of a 50 MW_t level combustor underway.

3) High temperature air heaters have not been successful. The near term alternative is use of oxygen air enrichment at a 3 to 4% efficiency loss, while development continues.

4) Steam Bottoming Data is encouraging - Argonne National Lab has successfully used soot blowers to strip MHD-type ash from boiler tubes and tests at the Coal Fired Flow Facility indicate SO_x and NO_x are well below EPA New Source Performance Standards.

5) A super conducting magnet of 6.2 Telsa has been built and tested at Argonne National Laboratory.

6) A successful DC-AC inverter was developed by the Electric Power Research Institute and installed at the Component Development Integration Facility.

7) Spinoffs have occurred - atmospheric slag rejecting coal combustors - low NO_x combustors - high temperature heat exchangers - hot gas (plasma) research, etc.

The MHD Users Group made up of 26 member electric utilities comprises the Edison Electric MHD Task Force. This group represents the major utilities of the United States using fossil fuels. The utility industry complex is represented by the MHD Industrial Forum which includes utilities, utility component manufacturers, suppliers and engineering, design and construction firms. Several have no government MHD contracts, but see the potential of the technology.

All this is encouraging, but if MHD is to prove its commercial viability, an integrated proof-of-concept facility is needed. How do we get there? The major concensus of the utility and industrial suppliers is that the quickest and cheapest approach is to couple an MHD plant to a conventional coal-fired plant. A multi-year program, directed to a proof-of-concept facility, is essential if MHD is to come to fruition.

I am greatly encouraged by the Department of Energy's turn around in pursuing an MHD Program. I have met with Secretary Hodel and Assistant Secretary Vaughan on this subject matter recently and hope to continue participating in negotiating an acceptable program that will provide a proof-of-concept facility.

I am advised that the present proposal of the Department of Energy envisions a facility having an electric capability of approximately 20 megawatt electric (MW_e), of which 12 MW_e would be a bottom unit or conventional steam generation facility with a 6 to 8 MW_e MHD unit and allied facilities involved in the actual MHD component.

I would like to again suggest that we work out an arrangement whereby Montana Power Company's 60 MW_e gas-fired Bird Plant located at Billings, Montana be utilized as the bottom unit of a pilot project, with a coal-fired MHD topping unit of approximately 30 MW_e size. Montana Power Company is willing to commit the Bird facility to such a project. While undoubtedly there would be some required modification of the Bird unit, I believe there is substantial savings to be gained by using an existing facility, since there is limited research advantage involved in building a 12 MW_e conventional unit associated with a ground up facility.

In this manner, it is my firm belief that many more dollars can be available for the basic MHD topping unit instead of being spent on conventional bottoming components and the sizing would be such to give the industry more reliable information in operating a proof-of-concept facility. I am hopeful of discussing this matter further with Assistant Secretary Vaughan and the Department of Energy in the immediate future.

It seems to me that it makes good economic sense, to utilize what conventional facilities might be available and direct our research and development dollars to the greatest extent possible towards the research and development of the MHD unit and its allied facilities.

The utility industry in the study funded by the State of Montana Department of Natural Resources and Conservation outlines a set of qualitative performance requirements which should be met before the utility industry could, with reasonable expectations, proceed with commercialization of the technology. Serious thought must be given to building a system large enough to address the varying levels of scale-up risk for the different components. The system must be large enough to provide confidence in extrapolation of the data to a commercial sized unit to the utility suppliers as well as the utilities. This confidence is necessary to establish the very important Industrial Base. The recent Congress requested study "Magnetohydrodynamics (MHD) Program Evaluation," May 5, 1983, by Gilbert/Commonwealth for DOE also recommends larger proof-of-concept plants, preferably as an add-on to a commercial steam plant.

The opportunity for international participation in the MHD program should be authorized by the Congress. In the past Japan has shown considerable interest in a joint ventured pilot project. I believe the government and Congress need to demonstrate its commitment to a multi-year program and demonstrate its reliability as a responsible partner with the utilities and industry to generate continued and increased cost shared participation. The industry has contributed substantially in the past and I believe wants to participate in a solid MHD development program.

In summary, I believe the current MHD technology has progressed to a point where a multi-year program must be established to demonstrate its technical and economic viability. S. 1278 provides a vehicle, in form, for Congress to authorize such a multi-year program. MHD offers our nation exceptional opportunities to replace dwindling oil reserves with coal in our total energy mix; to conserve our lone abundant energy resource by making the most efficient possible use of coal; to burn coal in the most environmentally acceptable, efficient manner; to facilitate the ability of utilities to meet national energy goals, and to offer the user of electricity hope of genuine progress being made in combating the escalation of the price of that energy form. I believe continued support for MHD is an imperative in the context of the national interest. Thank you for your attention and consideration.

Senator **Melcher**. Thank you very much, Joe.

Mr. Podolny.

STATEMENT OF WILLIAM H. PODOLNY, VICE PRESIDENT AND GENERAL MANAGER, FUEL CELL OPERATIONS, POWER SYSTEMS DIVISION, UNITED TECHNOLOGIES CORP.

Mr. **Podolny**. Mr. Chairman, thank you for the opportunity to speak in support of S. 1925.

I am vice president and manager of the Power Systems Division of United Technologies Corp. And with your permission, I'll submit my formal testimony for the record, and just make a few points.

The particular issue in the bill that we would like to address is the wedding of coal gasification together with a new form of power generation called the Fuel Cell Powerplant.

Back in about 1958, our corporation was in the MHD business, along with fuel cell and other means of power generation as a research project for the future.

We actually competed with Dr. Candorwitz, and ran a small 15-kW generator. We might have made the wrong choice, but since that time our company's invested more than $150 million in fuel cell powerplant technology.

Our future customers, the electric utility industry, the gas utility industry, in the form of a lot of different individual companies, have matched that or more. And over the last few years since the oil embargo, there has been support by the U.S. Government through the Department of Energy.

We have reached the point with the fuel cell powerplant where it's one of the few new technologies of the last decade that at least has established some measure of proof of concept, I guess, in the words of Secretary Vaughan.

We have run a small 5-megawatt powerplant, and demonstrated all of the inherent features on the grid of an electric utility, showing all of the basic fuel conversion efficiencies, environmental index citing and all the rest.

The wedding of the fuel cell with the gasification of coal is, I think, the ultimate wedding. Because fuel cell powerplants, of course, is a noncombustion process, but it is a chemical conversion, or electrical chemical conversion to electricity, and it's one of the most promising and highest efficiency conversions to electricity as a simple process.

It has one of the features of also providing for a total energy efficiency which is extremely high, almost 80 percent; because you can recover very large portions of what you might call the waste heat.

And we're doing that now in a number of sites throughout the country, demonstrating 80 percent utilization of the feed stock.

At the present time, we're underway with a relatively massive program, all private sector, trying to work with utilities in the United States and Japan to introduce some, about 23 different machines, which would run about 240 megawatts total of installed capacity. We would have to have those machines sold and installed and operating within the next 5 to 7 years.

We've gone through the up and down of the oil embargo, "thou shalt not use oil," the Post, Dr. Schlesinger's position, "thou shalt not use gas". And in the end we have always looked toward the wedding of coal and fuel cells as being extremely optimum.

With the ongoing event of our bringing machines into the first practice, the opportunity that's promised in the bill, in S. 1925, to show the coupling of coal gasification with fuel cell powerplants, either integrated or disconnected, is a most promising thing towards the ultimate conservation of energy, maximum utilization of coal, a definite contribution to economic environmental benefits and with no resultant consideration from those factors, and the promise of still future benefits to come, because we're talking about essentially the first generation of a technology which can only grow in increased efficiency.

We support this program. We take one point with the Secretary's statement earlier in the day about the question of where the risk is. He speaks of risk, high-risk programs being the Government's position, and then as you move toward demonstration it should move toward private sector. I think that's a little unsophisticated.

When you bring in new technologies, new power technologies which have great demands for meeting the installed cost of existing competitors, operating costs of existing competitors, providing for the reliability and the durability that people have associated with for the last 70 years with classic concepts, steam boiler, burners and all the rest, and overnight bring in a commercial product which is again a highly integrated, complex new set of componentry and ask your future customers to accept this novel technology, the risk is massive in terms of marketing and financial portions of the program. And we disagree that the place and the proper place, especially when we talk about energy security and promoting the use of our God-given resource here in the United States, that they should be so cavalier about the point where the Government should be supporting programs.

These programs in S. 1925 should be demonstration and development programs. They should be continuous even after the 5-year period, because it's from the errors of omission and commission that we'll learn how to do properly. And I think there should be strong government support of a very large percentage.

Thank you.

[The prepared statement of Mr. Podolny follows:]

TESTIMONY OF

WILLIAM H. PODOLNY
VICE PRESIDENT AND GENERAL MANAGER
FUEL CELL OPERATIONS, POWER SYSTEMS DIVISION
UNITED TECHNOLOGIES CORPORATION

BEFORE THE
COMMITEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

APRIL 9, 1984

Mr. Chairman and members of the committee, thank you for the opportunity to testify in support of S. 1925, the Coal Sciences Act. Fuel cell power plants are identified in this bill as electrical generating systems that will permit the utilization of coal-derived fuels at competitive cost and within the most stringent environmental constraints. We strongly support that position and we endorse the engineering and development program that leads to an electric utility phosphoric acid fuel cell generating system using coal-derived gas at a size of 10 to 50 Mw.

United Technologies has established and confirmed the viability of phosphoric acid fuel cell power plants operating on an electric utility grid at the multi-megawatt level. Using traditional fuels such as natural gas and distillate oil, the 4.5 Mw system has achieved the remarkable fuel utilization rate of 9300 btu's per kilowatt hour of power generated. The experience also confirmed the system's extraordinarily minimal pollution characteristics and the power plant's ease and acceptance for siting in the most difficult and constrained locations. At 1/100 of that scale, i.e., 40 kW, several power plants are operating at a variety of sites throughout the country. These completely automatic power plants have achieved 40 percent electrical generating efficiency, with an additional 40 percent efficiency recovered as thermal energy for the individual sites.

The ability to operate similar equipment on coal-derived gas is neither operationally nor technically limited. The fundamental issue that remains to be resolved is the cost and performance associated with the gasification of coal.

United Technologies is presently engaged in formulating a major program to deploy large-scale fuel cell power plants with a major investment by utilities in the United States and overseas. We are completing the details of a joint venture that will deploy 250-300 Mw of fuel cell capacity across the United States by 1990. All of the machines developed under this program can incorporate the capacity to operate on gas from coal. If the equipment produced under this program were configured in stations of 30, 50, or 80 Mw, it would be compatible with the type of gasifiers now being used at existing sites and planned for future demonstration sites. In that context, the overall performance of either an integrated gasifier/fuel cell system or a disconnected gasifier/fuel cell system can equal or exceed the performance of any other state-of-the-art or near term integrated or disconnected electric generation process based on gasified coal.

During the four to five years of development that precede the deployment of these multi-megawatt fuel cell power plants, we estimate that improvements in phosphoric acid technology will allow a 5 to 7 percent improvement in performance. In addition, we expect installed cost to decline between 30 to 40 percent in that same time period. At that level of cost and performance, a phosphoric acid fuel cell power plant coupled with a gasifier would be very competitive in cost with any alternative system. It would be environmentally superior to any other coal-based system. Finally, it would be an important part of the solution to the issues of coal transportaton, distributon, and handling that arise in most site-specific proposals.

The installation of central gasification sites, together with a limited gas distribution system, and fuel cell power plants at the point of utilization provides an optimum solution to the provisioning of energy from coal. Such a system provides the most cost effective, most efficient, and most environmentally acceptable method of providing energy from coal for a variety of end uses.

The proper approach for an engineering and development program for a gasifier/fuel cell power plant is not a singular demonstration event; rather, it is an on-going, working power system at a utility site to develop and refine a coal gasifier/fuel cell electric generating system.

The ultimate beneficiary of these efforts is the nation at large. Our recommendation can meet the worthwhile objective of highest availability and lowest cost energy service utilizing a domestic fuel resource with maximum conservation and minimal environmental impact. Modular and dispersed power generation which reduces planning uncertainty and construction lead time conserves scarce capital resources. As we strive to achieve commercialization as expeditiously as possible, we are convinced that the fuel cell is becoming more and more valuable to society as an extraordinary, cost effective technology to provide energy service.

The balance of this testimony examines the fuel cell power plant technology program in the department of energy budget proposed for FY 1985. The ability to move forward and take advantage of the benefits of a fuel cell coupled with a coal gasifier is dependent on an adequate federal technology program that complements the major venture being undertaken by the private sector.

The proposed Department of Energy fuel cell budget threatens to compromise the only viable effort to make fuel cells a commercial reality. Unlike other potential fuel cell manufacturers, United Technologies has demonstrated its ability to produce, design, fabricate, install and operate a number of fuel cell power plants. The promises of others to improve efficiency, reduce cost, or increase durability are not supported by any performance data from full scale components let alone complete power plants operating in the field.

An appropriate level of funding for phosphoric acid fuel cell power plant technology development at United Technologies in FY1985 is $18 million. This includes $12 million for the United Technologies electric utility multi megawatt water cooled technology programs, including fabrication and testing of experimental configurations of major components and subsystems: the reformer; the inverter; the stack, the control system; the thermal management system; and, the water treatment system. This also includes $6 million for the United Technologies gas industry multi kilowatt on-site technology development program.

The advanced research and technology development budget should include an additional $4 million for continuation of the United Technologies investigaton of phosphoric acid advanced technology. Molten Carbonate fuel cell activities at United Technologies should be funded at $5.5 million in FY85. The United Technologies program is the only one to have operated multi-cell stacks and identified potential solutions to the significant technical issues that have been defined.

The 4.8 Mw programs have become a bench mark of fuel cell viability for the electric utility industry. In order to assure the continued commitment of the utility industry to bear the major risks in bringing commercial fuel cell power plants into service, we believe that it is critical that the industry have this operating power plant available during the development period as a means of providing critical operational and durability information. A decision to refurbish and modernize, where feasible, the New York City power plant would provide extended reliability, performance and endurance testing that is necessary. A program funded at $5.5 to $6.5 million per year would provide that critical data and experience from an operating fuel cell system.

United Technologies is persuing a path of fuel cell commercialization that calls on the private sector, including utilities and the manufacturer, to make a several hundred million dolar investment in prototype and semi-production fuel cell power plants during the next several years. Parties to this private-sector venture cannot be asked to accept financial and technical risks that go beyond the limits of prudent business practice. For the manufacturer and potential customers to accept these risks, a broad-band federal technology program is essential. It is time to focus federal resources on that program that has a high probability of success in acheiving commercial service. That fuel cell program which has a solid record of technical performance and an unbroken history of commitment to commercialization deserves first claim on federal resources.

Senator MELCHER. Thank you.

Now, the last one on the panel, Mr. Irving.

STATEMENT OF WILLIAM M. IRVING, DIRECTOR AND ADVISORY BOARD MEMBER, MHD INDUSTRIAL FORUM, ACCOMPANIED BY DAVE BROWN, PRESIDENT, BOARD OF DIRECTORS, MHD INDUSTRIAL FORUM; JACK M. SHERICK, PRESIDENT, MSE, INC.; AND Y.C.L. SUSAN WU, PROFESSOR OF AEROSPACE ENGINEERING, UNIVERSITY OF TENNESSEE SPACE INSTITUTE

Mr. IRVING. Mr. Chairman, I appreciate the opportunity very much to speak here, and particularly in support of Senate bill 1278.

My name is William M. Irving, vice president of power, Charles T. Main, in Boston, an international architect engineer.

I've formerly been vice president of Boston Edison, and chief executive officer of Jacksonville Electric Authority in Florida.

And it's in this utility part of my career where I did most of my effort in MHD. I believed in it then, I believe in it more strongly as time goes on, and as I view the accomplishments of our research to date.

I appear today as director and an advisory board member of the MHD Industrial Forum.

I have with me Dr. Wu of the University of Tennessee Space Institute, Mr. Sherick of Mountain States Energy, and Mr. Brown, president of the MHD Industrial Forum. Dr. Detra is not here, but I would appreciate, Mr. Chairman, if you would enter my formal testimony and the testimonies of those four named in the formal minutes of this meeting.

Senator MELCHER. Yes, your testimony and theirs will be made a part of the record.

Mr. IRVING. Thank you, sir.

Senate bill 1278 runs a close parallel to the effort that we in the MHD industrial forum performed last year. And, we submitted a report to this body on this similar subject. This was entitled "A Strategy for Early Development of MHD for the Generation of Electric Power," and an executive summary is attached to my formal statement.

This document was developed by involving key leaders in all facets of the MHD technical community, industry, R&D companies, universities, and architect engineers. I had the pleasure of chairing that group.

So the important thing—one of many important things on Senate bill 1278 is that it provides a focus—and I underline the word "focus." The MHD national program has required a focus for many, many years; as those of us that have been involved would attest.

And it focuses on the retrofit of an existing unit, but does not leave out the continued research necessary both to support this retrofit and to improve second- and third-generation units, particularly in efficiency and reliability.

It also recommends a multiyear congressional authorization.

Need for MHD. The load growth is coming back. It's now projected by the Department of Energy to be 3 percent per year in the electric utility production to the year 2000.

To be this accurate, at least it's close in all probability, and there are tremendous amounts of megawatts that must be installed in this country between now and 2000, and coal must serve as fuel for the lion's share of this generation.

Thus, we certainly want to utilize our coal efficiently, and MHD is the prime approach to doing just that. This was attested to in the energy conversion alternative study, ECAS, performed by GE and Westinghouse, among others, for ERDA. And MHD came out tops in both the efficiency and minimum environmental intrusion advantages.

In addition, the University of Tennessee Space Institute has demonstrated in the recent past that over 90 percent of the sulfur dioxide, or SO_x removal, and 30 to 50 percent of NO_x removal has been accomplished with the MHD process. This is well below the EPA new source standards.

As far as capital and energy costs, ECAS tells us that it's lower than all other new technologies considered, and 20 percent lower energy costs than conventional fossil-fired plants.

This equates to a reduction of $370 million in 1982 dollars in capital value for each equivalent 1,000 megawatt plant.

In addition, Gilbert Associates, in 1983, prepared a study for the Department of Energy at the request of Congress, and this study does confirm previous studies on MHD, and updates the technology.

The question—and I've heard it argued here today, is MHD ready for proof of concept; in other words, a retrofit plant?

I am convinced personally that it is. There are no scientific barriers of MHD. There has been marked progress in the past 10 years. The channel that we have operated at a 1,300 hour test and a projected 8,000-hour life, this is at the AVCO Research Lab.

A combuster, we have had a 400-hour test on the 20-megawatt thermal combuster at TRW; a 50-megawatt combuster is due to be delivered to the CDIF midyear this year; superconducting magnet, 200 tons, 6.2 Tesla magnet has been tested at Argonne with success.

The coal-fired flow facility at the University of Tennessee operating 28-megawatt thermal MHD generate with SO_x and NO_x reduced, as I indicated before. The CDIF in Montana, operating 50 megawatts thermal is producing electricity. At this point it's simulated coal, but when the new burner goes in it will be coal itself.

Arnold Engineering in Tennessee, successful short duration, 250-megawatt thermal tests. Converter—or the inverter DC to AC developed for EPRI, successfully tested. This was done by Westinghouse.

Diagnostic controls, considerable progress in this at Mississippi State University.

In Russia, they are designing a 1,200-megawatt thermal 5- to 600-megawatt electrical, schedule for in service in the late 1980's. This will be gas for future conversion to coal.

Do utilities want MHD? Yes. You have heard Mr. McElwain's testimony. In addition, in 1982, the Western Utilities Chief Executive Officer Conference endorsed a strong resolution advising funding of MHD in light of its tremendous increase in efficiency for utilization of coal.

We have an MHD Users Committee made up of representatives from utilities covering every large coal-fired utility in the country.

Yes on the private sector, as has been mentioned before, has invested over $50 million in MHD funds to date.

Why a retrofit? No. 1. The technology is ready. No. 2. It's the most efficient approach in cost and time to approach commercial.

We are not advertising this retrofit effort as achieving a commercial plant at that time. Hopefully, it could be. But we believe strongly that moving in this direction is the most efficient approach. Again, focus our national program in one area.

When we have a challenge we all work better, we all get our work done better. And if we have such a challenge as to have an MHD operating on existing utility unit by 1992, that is the challenge.

We use existing facilities. We involve the end user at the earliest possible time. We operate and test under actual plant conditions, not laboratory. Not belitting laboratory, but for the end user to be involved with this part of the program is clearly important to its success.

As to size, our study, the MHD industrial forum looked at a 50-megawatt electrical MHD topper. You have heard Mr. McElwain's kind offer of a 60-megawatt Bird Plant in Montana. This would reduce the required size of an MHD unit to the order of 20 megawatts, and, thus, the cost would be reduced tremendously, and probably result in similar end results without extrapolating the current technology as much as in the original plan.

Recommendations. We strongly urge the passage of S. 1278. Legislative authority is needed to proceed for joint Government and industrial planning. The Government takes the lead in formulating energy policy. Industry must work closely with the Government to develop the details of the program.

We are very pleased that the new Assistant Secretary for Fossil Energy has invited MHD to do this. Several weeks ago we met with him and, again, this week. This is absolutely necessary for the success of such a program.

Government must take a strong and a consistent lead. It can't be, as we've talked, up 1 year, down another, in different directions. It's got to be consistent in order to attract funding, the interest of private contractors and utilities.

We should work toward an appropriation of at least $42 million for fiscal year 1985, and plan multiple-year funding to achieve retrofit operation by 1992.

Mr. Chairman, again, it's been my pleasure to appear before you and share with you what I and my colleagues thoroughly believe and offer them for your advice.

Thank you, sir.

[The prepared statements of Mr. Irving, Dr. Deyra, Mr. Brown, Mr. Sherick, and Ms. Wu follow:]

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Statement of

Mr. William M. Irving
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for the

Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate

April 9, 1984

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Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to testify in support of Senate Bill 1278. My name is William N. Irving, Vice President and Manager of Operations, Power Division, Chas. T. Main, Inc. I appear today as a Director and Advisory Board member of the MHD Industrial Forum.

There is a growing concensus within the electric utility industry, its industrial suppliers, the MHD research and development community and some segments of the Federal Government that the introduction of MHD electric power generation into utility use within a decade is a realistic goal. This results from the important advances that have been made in MHD technology development over the past several years and the continued confirmation of MHD's economic and environmental advantages. The strong and urgent merit of S.1278 is that it provides a directed program focus for moving the MHD technology into commercial use.

In pursuing the merits of this legislation, I will address briefly background comments, what technically has been accomplished to date, private sector support, and the development of the MHD Industrial Forum's "Strategy for the Early Commercial Development of MHD for the Generation of Electric Power" which closely parallels S.1278.

Background

Magnetohydrodynamics (MHD) is an advanced application of Faraday's law which states that an electromotive force is generated when an electric conductor interacts with a magnetic field.

All commercial base load electric power plants operate on this principle. MHD represents an advance in conversion technology because it converts electricity directly from the combustion products of coal. MHD derives its high efficiency by passing a very high temperature, electrically conducting gas, called a plasma, through a magnetic field and extracting electricity directly. This MHD portion requires no moving parts. The gas exhausting from the MHD unit then drives a conventional steam power plant. This combination provides very high efficiencies and very low environmental emmissions.

It also should be noted that MHD is a direct conversion system. Fluidized beds and nuclear reactors are systems for converting fuel into heat which is then converted into electricity using conventional technology such as turbogenerators or fuel cells.

Of the many evaluations performed on MHD, the most extensive was the Energy Conversion Alternative Study (ECAS) performed for the Energy Research and Development Administration (ERDA) under NASA contracts by Westinghouse Corporation and General Electric Company.

This ECAS evaluated what ERDA identified as the seven most promising conversion heat engine technologies. As in previous studies, MHD again received the highest overall rank in terms of its efficiency and environmental intrusion advantages. Not only will NO_x, SO_x and particulate levels be less than the New Source Performance Standards, but water usage, thermal pollution, and the greenhouse effect will be substantially less than with other coal burning technologies. The University of Tennessee's MHD Center has demonstrated that 90% of SO_x and 30 - 50 % of NO_x can be removed with the MHD process. As a consequence MHD promises to be a major contributor to improving air quaility.

In terms of capital cost and cost of electricity, MHD was shown to be substantially less than the ECAS referenced steam cycle and lower than the other six systems. For example, the study suggested up to a 20% reduction in cost of electric energy compared to a conventional coal/steam power plant. This is equivalent to about 370 million dollars (1982 $'s) in capitalized value for each 1000 MW_e* plant.

A $270,000 study was completed by Gilbert Associates, Inc. in May 1983, for the Department of Energy in compliance with Congressional direction. This study, conducted by a design construction firm specializing in the utility field, essentially confirms the many earlier studies and updates the technology's status.

Technical Progress

Some of the technical progress made by MHD technology through Congressional appropriation support is as follows:

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* MW_e - Megawatt electric - The generator's electric power output.

1. The results of the over 1300 hours generator test performed at Avco Everett Laboratory (AERL) in show that 8000 hours' lifetime generators can be built and operated. Material erosion is not a problem and the high temperature can be easily handled with conventional heat transfer technology.

2. The 20 MW_t* coal combustor developed by TRW in California has successfully accumulated 400 hours of operation.

3. A 20 MW_t coal combustor developed by TRW has been integrated and tested with an MHD channel built by AERL.

4. The 50 MW_t coal combustor designed by TRW for use in the CDIF is scheduled for delivery in mid-1984.

5. The Argonne National Laboratory in Illinois built and successfully tested a 200-ton, 6.2 tesla superconducting magnet designed for MHD use.

6. The Coal Fired Flow Facility (CFFF), a major DOE center in Tennessee, is operating a 28 MW_t MHD generator with NO_x SO_x levels reduced to well below EPA's New Source Performance Standards. (Sulphur: 90% below EPA requirement; NO_x: 30% to 50% below EPA requirement.)

7. The Component Development and Integration Facility (CDIF), the Department of Energy's principal test facility, located in Montana, is operating a 50 MW_t MHD generator, producing electricity using oil to which ash is added to simulate coal burning. Coal-fired testing will begin later this year after installation of the TRW 50 MW_t combustor.

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* MW_t - Megawatt thermal - Heat input into generator.

8. The USAF Arnold Engineering and Development Facility (AEDC) in Tennessee has performed short-duration tests which clearly demonstrate the successful operation of near-commercial size (250 MW_t) MHD channels.

9. The DC to AC inverter developed for the Electric Power Research Institute (EPRI) by Westinghouse has been successfully tested.

In addition, it should be noted that the Soviet Union is operating a 250 MW_t electric power MHD plant, using natural gas, which feeds into the Moscow power grid. They are proceeding with the design and construction of a 1200 MW_t (500 - 600 MW_e) electric power commercial utility plant scheduled to be on line in the late 1980's and designed to convert to coal-fired operation.

Private Sector Support

The private sector - industry, utilities, private electric institutes and State and Local Governments have invested an estimated $50 million in development of the MHD technology, slightly more than a 10% match to the Federal Government's investment. This support in the private sector continues to grow and the following is representative of that interest.

1. Montana Power Company (MPC) submitted an unsolicited proposal to DOE for a joint feasibility study of MHD power generation. This would lead to cost-sharing arrangements between DOE and MPC for the placement of MHD on an existing power plant

site. The total contribution of MPC would be in excess of $100 million. The proposal was submitted early in 1981, but there has been no DOE response.

2. Southern California Edison independently funded the initial phases of a conceptual design for an MHD retrofit of its Etiwanda Power Station. This funding is at a level of approximately $200 thousand.

3. EPRI invested $2 million in the inverter being tested at CDIF and an additional $1 million for electric current consolidation.

4. The State of Montana has invested $500 thousand for studies of "Utility Determination of MHD Commercialization Requirements," and the "Engineering Assessment of the Functional and Operational Requirements for a MHD Advanced Testing System." Twenty-two utilities participated in these studies by providing approximately $250 thousand in supporting services.

5. The Edison Electric Institute (EEI) has an MHD User's Group Committee with a membership representing all of the major utilities using fossil fuel.

6. The Advisory Board of the MHD Industrial Forum includes distinguished leaders representing the electric utility industry, utility component manufacturers and suppliers, and engineering, design and construction firms.

7. The Committee which prepared the MHD Industrial Forum's "A Strategy for the Early Commercial Development of MHD for the Generation of Electric Power," included representatives from the

electric utility industry, its component manufacturers and suppliers and engineering and construction firms serving the utility industry.

8. The Western CEO Utilities Conference affirmed support for MHD and rejected the DOE's Energy Research Advisory Borad's (ERAB) report by resolution (attached).

This utility interest has been encouraged by the EPRI "Operational Analysis of Open-Cycle MHD" performed by Westinghouse, dated July 1980, which state that: "These results on a national level show that MHD has the potential to capture as much as 42% of the total coal unit additions projected to be added between 1995 and 2000." Also the "Comparative Study and Evaluation of Advanced Cycle Systems" conducted by the General Electric Company for EPRI, dated February 1978, contains various figures showing that MHD power plants could capture over 40% of the utility market after the year 2006.

Need for S.1278 Passage

With this background in mind I will now address the technical rational and the need for S1278.

This bill very closely parallels the study performed for the MHD Industrial Forum and entitled a "Strategy for the Early Commercial Development of MHD for the Generation of Electric Power." (The executive summary attached.) This study was conducted at the urging of many members of Congress and was presented to this committee last year. I had the privilege of serving as chairman of the study group which proposed the strategy.

The group consisted of representatives of the electric utility industry, electric power plant component manufacturers and suppliers, architectural engineering firms experienced in building power plants, industrial research firms, universities and colleges.

In developing this plan, we first evaluated the state of the technology. With that background, we assessed what would be required to design, construct and operate an MHD power unit on a utility site and integrated with an existing coal fired utility generator at the earliest possible time. We included costs, schedules and a suggested government/industry cost sharing plan.

Unlike previous proposals which called for a completely new power plant to be operational in the late 1990's, this Strategy centers around a "retrofit", e.g., the addition of an MHD unit to an existing coal-burning power plant. Since an MHD plant includes a conventional steam turbine, the retrofit MHD plant will utilize the existing turbine generator, cooling system, support functions and personnel on an operating site. In addition to being significantly less costly than a completely new plant, the retrofit will result in about a 50% increase in the host power plants' generation capability.

The retrofitted plant would be operational by 1992 with a nominal output of 120-130 MW_e of which 50 MW_e would be obtained from the MHD cycle. This size is optimum to provide all the reliability and operational data required by the utility industry for final commercial evaluation. It's cost would be far less than a full-sized demonstration plant. The plant size would allow optimum testing and operational flexibility under actual utility plant and operating conditions. The retrofit option also reduces environmental impact studies and permit requirements.

The initial retrofit may not actually be commercially viable but would provide the basis for commercial viability in the shortest practical time span through a consortium involving utilities, industry and the Government. One consortium possibility is:

- a utility to provide the retrofit site, program management, and operating personnel, with other utilities assisting the funding of commercially available components;
- private industry to provide component design, and fabrication, and engineering services at minimum profit;
- the Federal Government to continue funding the MHD program and furnish components resulting from this program;
- the State/Local Governments to assist in licensing and environmental studies to minimize delay and cost.

The total cost of the retrofit is estimated at $325 million (1983 dollars). The initial phase of the program wll explore various funding possibilities for the participants. One funding possibility is for the Government to furnish those components which will come from the MHD development program and for the private sector to furnish those components which are commercially available.

The Strategy suggests selecting a retrofit site while making financial arrangements in 1983 and 1984. Detailed engineering would start early in 1985 followed by the procurement of major components, and construction would start by 1986. Since the retrofit is the first of a kind, four years are allowed for construction. The MHD segment would be ready for test operation in early 1988, allowing most of 1988 and 1989 for modifications that may be necessary prior to the initial operation of the retrofit unit in late 1989 with expected utility operation by the end of 1990.

I want to emphasize that to achieve the 1992 target date for operation of a retrofit unit, as called for in S1278 and the MHD Forum's strategy, will require continuing and concurrent engineering testing and development activity at the existing MHD test facilities and development centers. This work is necessary to provide design and other data needed for the MHD retrofit unit. Indeed, to achieve its maximum promise through second and third generation plants, MHD, like any other advanced technology, will require a continuing research and development program well beyond its initial commercial operation.

It is the opinion of the Forum that private funds will be forthcoming when the industry sees that the Government is committed to a well-defined program within a clearly-defined time schedule. Several utility companies are already investigating MHD retrofit possibilities. The Montana Power Company earlier submitted a proposal to DOE to cost share in an MHD retrofit program. It should be understood however, that since the Government long ago assumed primary responsibility for high technology research and development, neither MHD nor any other advanced energy technology will achieve commercial use without Government support and leadership.

We recognize that S.1278 recommends an ambitious program. However, it is a far less ambitious program than that being followed by the Soviets who are now designing a 500 MW_e MHD plant. The schedule is consistent with the progress of the MHD technology development.

Passage of the Bill S.1278 will focus the national MHD program on:

1. An effort that focuses on essential technology tasks leading to an MHD plant that will operate on a utility site at the earliest possible time;

2. A financing plan that involves utilities, private industry and the Government;

3. A continuing research and development effort not only to support the commercialization goal but also for second and third generation plant improvements;

4. A well-defined time frame in which to accomplish all this, and

5. A multi-year Congressional authorization.

Let me conclude with a few remarks on the need for this Bill from a policy viewpoint. As you are aware MHD has received little support from the executive branch over the past years. This year, the Department of Energy proposed a $17.8 million scientific technology program. While representing a new attitude toward MHD, it failed to take proper account of the work which has been accomplished over the years and it gave little attention to pressing engineering development tasks. In addition, $17.8 million would not be sufficient to carry out the proposed program.

Fortunately, the new assistant secretary for fossil energy has invited industry to work with the Department to prepare a government/industry MHD joint program. We are hopeful that the resulting plan will reflect the goals of S1278 and the Forum's strategy.

However this DOE initiative does not make this bill unnecessary. In fact the bill comes at a very opportune time in that it enables the Congress to participate in formulating the national MHD development effort and will provide legislative authority for the current DOE/industry planning activity.

The bill also is appropriate since it has been the Congress which has taken the lead not only in MHD development but also in ensuring continued fossil energy research, development and engineering. This is no time for the Congress to relax its initiative in MHD or any coal related technology program.

The MHD Industrial Forum strongly urges your approval of S1278.

I have with me a number of colleagues who have submitted testimony for the record. We are available to respond to any questions you may have.

ATTACHMENT 1

RESOLUTION

The Western Utilities CEO Conference
January 13, 1982

The Western Utilities CEO Conference, meeting in regular Session on January 13, 1982, unanimously adopt the following resolution, and instruct the organization's Chairman to promptly convey this resolution to the attention of the members of the Energy Research Advisory Board of the U. S. Department of Energy in the most prominent and urgent manner available:

"WHEREAS, the Western Utilities CEO Conference is composed of Chief Executive Officers of all the electric utility companies serving the 13 western states, joined together to foster the mutual interest of America's electric power consumers and the electric utility industry, particularly in the western part of the U.S. and

WHEREAS, the effecient, flexible and cost effective generation and distribution of electric power is a vital component in the industrial and defense economy and capability of the U.S., and,

WHEREAS, the generation of electric power in the U.S. is seriously impacted by inflation, environmental restrictions, government regulation, high interest rates, high equipment costs, and a dearth if technology options, and,

WHEREAS, the use of this nation's immense coal resources for electric generation -- given appropriate technology for coal's clean and efficient use -- represents the feasible, long-term energy option, and,

WHEREAS, the Energy Research Advisory Board (ERAB) of the U.S. Department of Energy has recommended the virtual elimination of federal support for Research and Development of coal-using energy conversion technology; therefore,

BE IT RESOLVED -- that the Western Utilities CEO Conference strongly supports a national commitment to the use of caol for electric power generation in the U.S., as being in the best interests of the nation, electric power consumers, and the electric utility industry. The Western Utilities CEO Conference believes that magnetohydrodynamics represents one of the most efficient methods of utilizing our vast resources of coal for the generation of electric power, with greatly reduced environmental problems. We, therefore, urge ERAB to reconsider its no-funding recommendation on coal energy conversion research, and we recommend in particular that the MHD program receives continued support."

WESTERN CEO UTILITIES CONFERENCE

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Idaho Power Company
Montana-Dakota Utilities Company
Nevada Power Company
Pacific Gas and Electric Company
Pacific Power and Light Company
Portland General Electric Company
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Public Service of Colorado
Puget Sound Power and Light Company
San Diego Gas and Electric Power Company
Sierra Pacific Power Company
Southern California Edison Company
Tucson Electric Power Company
Utah Power and Light Company
Washington Water Power Company

Executive Summary

A Strategy for the Early Commercial Development of MHD for the Generation of Electric Power

February 1983

Prepared Under the Direction of
THE MHD INDUSTRIAL FORUM
Suite 805, 1725 Desales Street, NW
Washington, D. C. 20036

General

Magnetohydrodynamics (MHD) is an advanced power generation concept that can produce electricity from coal at the highest possible efficiency and the least possible impact on the environment.

The current MHD development program is directed toward the step-by-step development of MHD with the intent to place an MHD power plant in operation in the late 1990's. The MHD Industrial Forum has reviewed this program and recommends a strategy intended to place a plant into operation on a shorter schedule and at a reduced cost. The strategy centers around a "retrofit" or the addition of an MHD unit to an existing power plant. Since an MHD plant includes a conventional steam turbine, the retrofit MHD plant will utilize the existing turbine-generator, cooling system, and be at an operating site for which most support functions and personnel are already present. In addition to being significantly less costly than a completely new plant, the retrofit will result in increased power generation capability since the existing steam turbine-generator output will remain the same. The initial retrofit may not actually be commercially viable but would provide the basis for commercial viability in the shortest practical time span through a consortium effort involving utilities, industry and the government. One consortium possibility is for:

- A utility to provide the retrofit site, program management, and operating personnel, with other utilities assisting the funding of commercially available components;

- private industry to provide component design, and fabrication, and engineering services at minimum profit;

- the Federal Government to continue funding the MHD program and furnish components resulting from this program;

- the State/Local Governments to assist in licensing and environmental studies to minimize delay and cost.

MHD has been considered a promising alternative for the more effective use of fossil fuel for some years. A few years ago, it became clear to some of the electric utilities that the technology had advanced far enough that some specific application should be made. In 1980, a utility group met to start work on the technology application effort.

The important thrust of this program is seen by the utilities group as being the retrofit of existing power plants. Oil-fired and coal-fired plants are both candidates. Several utilities have developed conceptual retrofit designs, and the utility MHD Users Group is working on the identification of power plants that could be candidates for retrofit. At the same time, the Users Group is working with the Pittsburgh Energy Technology Center to design the components of the Federal programs necessary for the first retrofit plant. The interest in such a retrofit is because of the improved efficiency, reduced site problems, oil replacement, the promise of acceptable environmental impact, and reduced capital demand. A retrofit would meet many requirements even though it did not meet the ultimate potential of a final system.

The long-term future does demand a continuing research and development program but success of the retrofit would provide an industrial base from which additional improvements can be derived. These improvements, coupled with research and development, are the approach most likely to lead to the most efficient fossil fuel power plant at the least development cost.

MHD Concept

In this concept, coal is burned using oxygen enriched, preheated air to obtain a high temperature. A small quantity of potassium carbonate is added making the resulting combustion gas electrically conductive. This gas is passed through an MHD channel surrounded by a superconducting magnet resulting in the production of electric power. The gas which leaves the MHD channel is still very hot, and goes to a heat recovery boiler which generates steam to drive a conventional steam turbine-generator for the further production of electric power. Using current technology, an MHD plant would have an overall thermal efficiency of about 40-50 percent as compared to about 32-34 percent for a conventional steam plant and will require only about 75 percent of the fuel. There is the longterm potential for increasing the thermal efficiency of an MHD plant to about 50 percent, which would reduce fuel requirements to less than two-thirds that of a conventional plant.

The potassium combines with any sulphur in the coal to form potassium sulphate which can be removed with the coal ash prior to discharging the flue gas to the environment. A 95 percent or greater sulphur collection efficiency is expected which equals or exceeds the best SO_2 removal efficiency using current scrubber technology for conventional plants. When combined with the lower sulphur input (less fuel used), an MHD plant can greatly reduce the amount of sulphur compounds discharged to the environment. The potassium sulphate is processed back to carbonate for reuse.

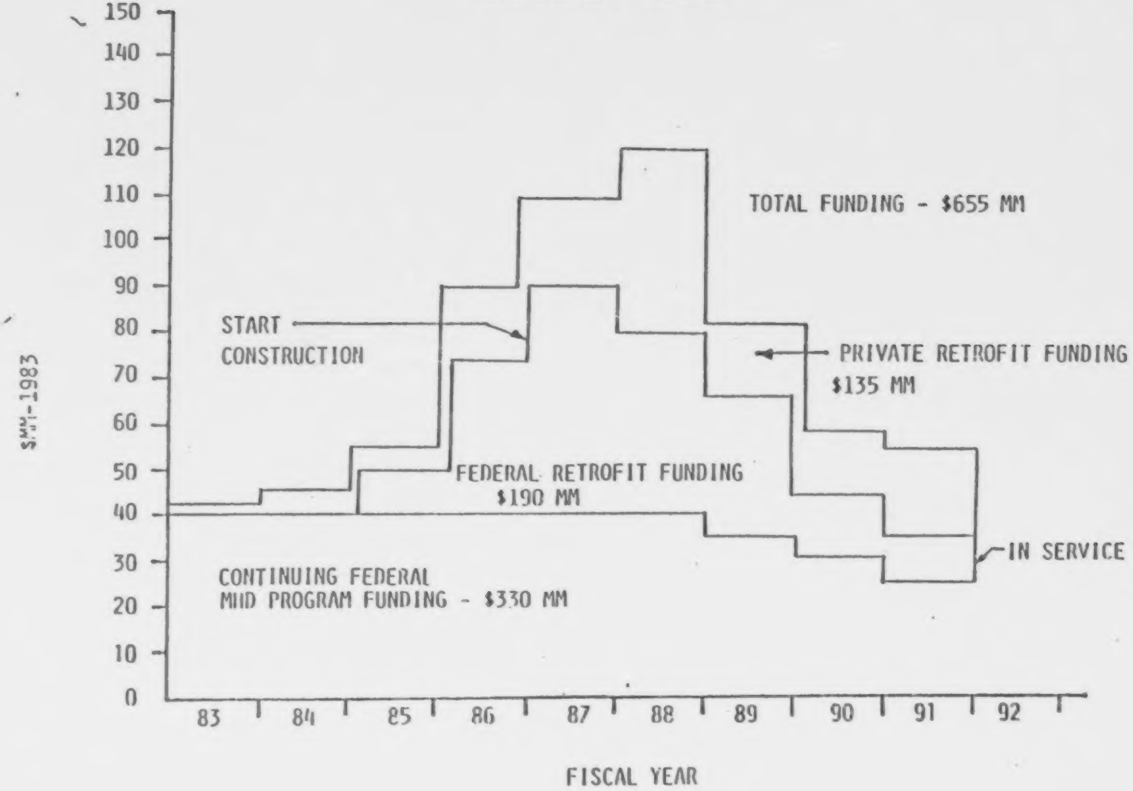
Funding

The 1983 cost of the retrofit is estimated at $325 million. This is in addition to continued funding of the present MHD development program at a level of $40 million through 1988 and reducing $5 million per year thereafter which represents a total of $330 million through the end of 1991. The attached cash flow chart illustrates the estimated funding for the proposed MHD development program.

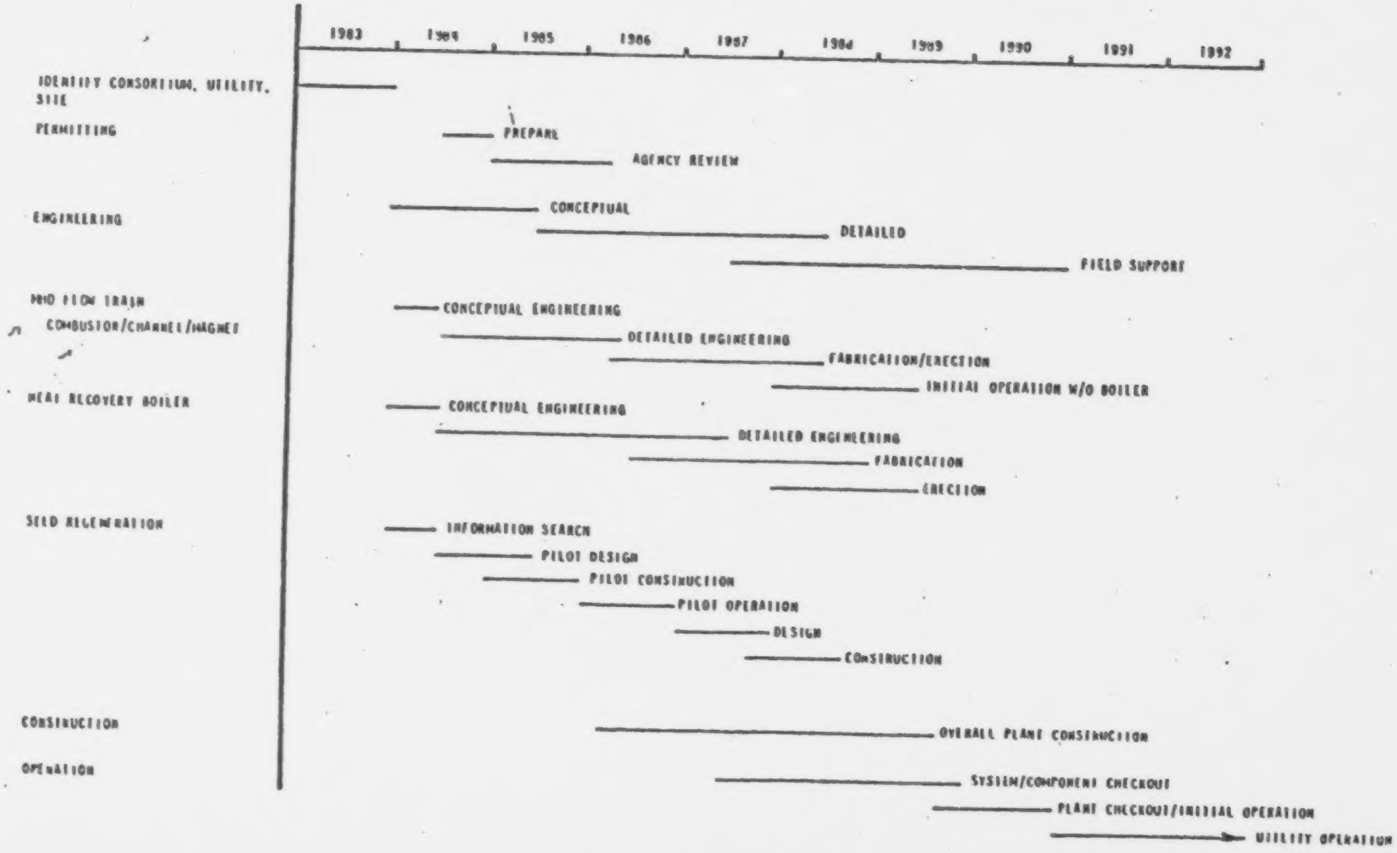
Schedule

It will be necessary to select and confirm a retrofit site and obtain firm financial arrangements for the entire project prior to the commitment of any major expenditure. 1983 and 1984, are allowed for this activity. Detailed engineering would start early in 1985 followed by the procurement of major components, and construction would start by 1986. Since the retrofit is the first of a kind, four (4) years are allowed for construction. The MHD flow train consisting of combustor, channel and magnet would be ready for test operation in early 1988, allowing most of 1988 and 1989 for modifications that may be necessary prior to retrofit initial operations in late 1989. The heat recovery boiler is a major original engineering effort and represents the critical path. Plant checkout and initial operations are shown from the middle of 1989 into late 1990. Initial operation of the retrofit would start in late 1989 with expected utility operation by the end of 1990.

ESTIMATED
FUNDING FOR MIID DEVELOPMENT PROGRAM
1983-CONSTANT DOLLARS



MHD RETROFIT SCHEDULE



Statement of

Dr. R. W. Detra,
Vice President and General Manager,
Avco Everett Research Laboratory, Inc.
2385 Revere Beach Parkway
Everett, Massachusetts 02149

for the

Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
9 April 1984

I am very pleased to present this testimony on behalf of this long-awaited Bill setting forth a national MHD electric power generation development effort focused on bringing MHD technology to commercialization. For many years the MHD community has been urging the Government to proceed with a development program focused on early commercialization of MHD Power generation. This Bill does that.

The superior operating efficiencies and economic and environmental advantages of MHD power generators have been well documented by repeated studies. The first was conducted by the American Electric Power Corporation in the early 1960's and most recently by Gilbert Associates, Inc., for DOE at the direction of the Congress. System studies and plans for bringing the technology to commercial use also have been addressed.

Since you will hear about these areas from other witnesses, I will limit my testimony to the following question: Is the technology available to proceed with the engineering work required to meet the proposed legislation's objective of operating an MHD unit on a utility site in 1992? The answer is an unequivocal "yes."

An MHD generator consists of a combustor, a channel contained within a magnet, and an inverter. Coal, oil or gas is burned in the combustor to produce a 4500°F gas to which potassium is added to increase conductivity. The conducting gas enters the channel at high speed where it interacts with the magnetic field force to produce electric current which is tapped off through electrodes in the channel wall. The inverter changes the direct current (DC) to alternating current (AC).

MHD generators have operated successfully for many hours both in the United States and the Soviet Union. At our Laboratory in Everett, Massachusetts, we have built and operated channel electrodes for over 1300 hours, and we are confident that we can build an 8000-hour channel. At TRW, as you have heard from Dr. Sellers, MHD coal combustors have been successfully tested and a 50 MW_t* combustor is being completed at TRW for installation in the CDIF in early summer. TRW's 20 MW_t coal combustor was successfully tested with an MHD power generator at Avco Everett

*Megawatt thermal - MW_t is heat input into channel.
Megawatt electric - MW_e is the power produced by the generator.

Research Laboratory two years ago. Unfortunately, these tests were terminated not for technical reasons, but for lack of funds. The Westinghouse inverter, developed with EPRI funding, has been operating at the Component Development and Integration Test Facility (CDIF) without problems. An Avco-developed MHD inverter also operated successfully.

Superconducting magnet technology has been well in hand since the advent of stabilized superconducting material, which I am pleased to say was invented at Avco. Very large superconducting magnets are in use in national laboratories and universities and there is no reason to suspect that superconducting magnet technology presents any scientific problem for MHD use.

Two principal tasks remain in MHD generator development. The first is long-duration, coal-fired testing at the 50 MW_t CDIF with supporting work at the smaller 20 MW_t test cell at Avco. The second task is to use this information to determine scale up parameters for the components for the next MHD unit. I believe that unit should be on the order of 20 MW_e - 50 MW_e and should be operated on a utility site, preferably as a retrofit to an existing steam generator.

The suggestion has been put forth in the FY 85 budget request that a series of intermediate test facilities are required before installing an MHD unit on a utility site. These facilities are unnecessary technically, would add many more dollars to the program, and would guarantee stretching the development schedule many years beyond the 1992 goal established in this Bill. Consider that an 80 MW_t integrated unit is not much larger than the 50 MW_t CDIF facility (6 MW_e vs 4 MW_e). The incremental benefits from the 80 MW_t facility do not justify the enormous time and expense required either to modify the existing CDIF or to build a new facility. Comparable effort would be better expended on the suggested retrofit plan which represents a truly significant technical advance and a major step towards commercialization. With modern computer modeling techniques all the design and engineering information needed to scale up to a retrofit size of 20 MW_e - 50 MW_e (150 MW_t - 350 MW_t) can be developed from the CDIF and other existing test facilities.

To achieve the very high efficiencies and economic advantages promised by MHD, it is necessary to take advantage of the heat remaining in the gas as it exits from the MHD generator. This is done by using the exiting gas to fire the boiler of a conventional steam turbine power plant. This may cause boiler problems that, although well understood in principle, need to be addressed from an engineering and design viewpoint.

Likewise, the economics of MHD require recovering the potassium seed from the gas exhaust and recycling it back to the combustor. The potassium also plays a key role in the removal of the environmentally polluting oxides of sulphur which it does by combining with that chemical to provide potassium sulphate. The oxides of nitrogen the other major air pollutant are controlled by the MHD technology as explained by Dr. Susan Wu, Director of MHD at the University of Tennessee's Space Institute in her testimony.

The scientific questions associated with all these issues relating to the bottoming cycle (all activity downstream of the MHD generator) have been answered. What remains are the engineering problems which the coal-fired flow facility (CF^3) at the University of Tennessee has been designed to solve. Here again, as with the topping cycle, delays have been caused not by technical problems but by funding limitations. The work being done at the CF^3 is excellent.

It is now being suggested that to achieve valid downstream component test results require moving the CF^3 to Montana and integrating it with the CDIF.

This is unnecessary since the CF^3 data can be integrated with the CDIF data to obtain the information needed to design an MHD unit for retrofitting to a steam turbine power plant. Obviously, integrating a CF^3 unit at the CDIF would represent a very conservative and safe approach but certainly not of sufficient value to justify the estimated $30 million cost and five-year timetable to make such a move.

Finally, let me address the Gilbert Associates study. This is an excellent assessment of MHD which includes undeveloped technologies such as high-temperature preheaters and advanced materials intended for use on second and third generation commercial MHD units. It should be understood that they are not necessary for the first generation models we are addressed in the bill.

Avco Everett Research Laboratory has had a long association with MHD dating back to 1959 when it developed the world's first successful demonstration of an MHD generator. In the ensuing years we have contributed to every facet of MHD technology including superconducting magnets, high-temperature preheaters, and inverters, as well as channels and combustors. We presently operate the most extensive MHD research test and development facility in the private sector. We also have been associated with all the MHD evaluations and assessments dating back to the American Electric Power study of the early 1960's when MHD development was being funded by Avco and a group of utility companies.

Based upon this long and intimate experience with MHD, I can assure this committee that the technology now available justifies going forward with the program outlined in this Bill, and I urge early adoption of S.1278.

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PRESENTED TO

SENATOR PETE V. DOMENICI
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SUBCOMMITTEE ON ENERGY, RESEARCH AND DEVELOPMENT
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UNITED STATES SENATE

APRIL 9, 1984

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Mr. Chairman and Members of the Subcommittee:

I am very appreciative of the opportunity to submit testimony today in support of S.1278, the Magnetohydrodynamics Research, Development and Demonstration Policy Act of 1983 sponsored by Senators Melcher and Stennis, and others. We also strongly support S.1925, Senator Byrd's bill to establish a national coal science, technology and engineering development program and urge the Subcommittee to include within the legislation support for the national MHD program.

In our judgment the public interest and the national need require a balanced energy research, development and demonstration program that includes coal, oil, gas, nuclear, fuel cells, solar and other advanced and innovative technologies in a program that is financed to reflect that national need and interest. It is not good public policy to virtually ignore coal technology development, as has been the case in recent Administration budgets, while we continue to depend on fuel imports. The government must also take the lead in this effort since it long ago assumed primary responsibility for high technology research and

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development. Neither MHD nor any other advanced energy technology will achieve commercial use without government support and leadership.

At the request of the Subcommittee staff we did not seek to testify during the public hearings on the FY 1985 Department of Energy budget because this hearing was imminent. I have therefore attached to this brief statement the MHD Industrial Forum's comments concerning the FY 1985 budget request for MHD. I would like to emphasize that industry is working closely with DOE to focus development of the MHD technology toward the earliest possible commercial use. We applaud and firmly suppport Assistant Secretary Vaughan's initiative in this regard.

A number of the Forum's members are here today to back up the testimony of Mr. Joe McElwain and Mr. William Irving. We are available to answer any questions you may have concerning the MHD technology or our support of S.1278.

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Dear Mr. Chairman and members of the Committee:

I am submitting testimony in support of a continuing national Magnetohydrodynamics (MHD) program directed toward commercializing this technology as soon as possible. However, in deference to the newly appointed Assistant Secretary for Fossil Energy, William Vaughan's invitation to the MHD Industrial Forum and the Edison Electric Institute's MHD Utility Task Force to work with DOE on a national MHD development program, we ask to reserve our final position on program direction and funding. Industry still supports a $40 million DOE FY 1985 MHD program over DOE's $17.8 million budget request.

The FY 1985 budget request of the Administration for developing MHD power generation is a most welcome change from past years. We are particularly pleased that the changes in high level department personnel have included individuals who recognize the importance of fossil energy and coal. Recent discussions with William Vaughan have been very positive and encouraging. This is not only because of his apparent positive attitude toward development of the MHD technology and fossil energy in general but also because of his desire to involve

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industry in the planning of the Department's MHD program. It is most unfortunate, however, that DOE planners did not seek the counsel of industry prior to proposing a program intended to place the private sector in a position to commercialize the MHD technology.

While the Forum is very positive about DOE's MHD program direction and the new Assistant Secretary's request for industry involvement, we must point out for the record the problems with the FY 1985 budget submission. Unfortunately, the budget and plan which Mr. Vaughan inherited from his predecessor (which is contained in the budget before this Committee) was not presented with a continuing national MHD program in mind, especially given the low budget request and the requirement for fifty percent private cost share as a pre-condition for continuing the present program. The proposed multiyear program concept is essential. However, the technical portion (Phase I) of the plan ignores the state of the MHD technology. The purpose of the Phase I scientific research program appears to emphasize the basic research activities which were the focus of the program in the early 1970's rather than the research needed to support the engineering scale-up required at this stage of MHD technology development. The proposed Phase I concentrates on the wrong problems. The proposed Phase II 80 Mw thermal integrated test facility (ITF) operation would presumably abort all ongoing work at the 50 Mw thermal scale at the Component Development and Integration Facility (CDIF) and supporting component manufacturers just at the time when the first critical coal fired topping cycle tests are being initiated. In addition, the ongoing bottoming cycle test program at the Coal Fired Flow Facility (CFFF) may be discontinued in mid-stream. If true, these terminations would be a tragic waste of the more than $300 million that has been invested to date just to get that test data. An integrated test facility at the 80 Mw thermal level as an end to the government program will not meet the needs of the utility industry, nor meet the government's goal of developing an adequate knowledge base that will enable private idustry to apply the technology. The proposed program cost estimates are so low that a cost overrun is guaranteed.

While this is not the place to go into a detailed technical evaluation of this plan (which we are doing with the department), a quick overview of DOE plan deficiencies will be useful. The DOE Phase I scientific research program proposal identifies a variety of technical issues associated with MHD which it indicates must be resolved. In fact, the budget description of these issues appears to be a cut-and-paste job of old documents found around the office. Let me address some examples. The development of high temperature air heaters is identified as a critical problem. The fact is high temperature air heaters will not be needed for first generation MHD plants, since the high temperature requirements can be met using oxygen with little or no economic impact to plant operation. Design and operating conditions required to suppress ash fouling effects were identified as a critical scientific problem when in reality, they are engineering questions which are being resolved at the Coal Fired Flow Facility (CFFF) at the University of Tennessee. The recovery and regeneration of potassium salts and seed are also engineering problems whose solution the CFFF was designed to provide.

Coal combustors and channels were identified as areas needing research to obtain data on erosion, corrosion, combustion kinetics for different coal types. These again are engineering questions which cannot be resolved through small scale tests. They must be resolved through engineering testing in facilities such as those presently being used at Avco, TRW and the CDIF. Superconducting magnet technology is well established and "additional" research is not needed. A superconducting magnet needs to be designed for use in a large scale MHD power plant, but this is not critical and can be delayed. Current consolidation, power conditioning and inverter circuitry have worked well at

Avco and the CDIF. While improvements are desirable in all the above areas, the state of the art of all these systems is sufficiently advanced and none are "show stoppers" for achieving early commercial MHD plants.

The accomplishments which the new DOE FY 1985 plan calls for would be of "scientific" interest but of little engineering value. They address problems that already have been solved and do not allow for proceeding with the more pressing MHD technology engineering questions. For example, efforts like the following must be completed as quickly as possible: completion of the coal combustor at TRW and its installation at the CDIF for coal-fired testing; continuation of coal-fired MHD channel testing at Avco's 20 Mw thermal test facility; provision of the necessary equipment and operating funds to the CFFF to enable that important facility to complete seed regeneration, environmental control technology engineering development and other critical bottoming cycle development.

The results of CFFF engineering, the channel work at Avco, the TRW combustor effort and diagnostic and instrumentation control equipment work at Mississippi State University need to be integrated quickly into the CDIF as the final step before any near commercial demonstration. The DOE MHD plan for FY 1985 ignores the well thought out merits of its existing program and contemplates taking no advantage from several years of progressive and productive MHD technical work.

The concept of an integrated test facility (ITF) is strongly supported by the industrial and utility sector. However, a scale of 80 Mw thermal as proposed in DOE's Phase II is not much larger than the present 50 Mw thermal test capability at the DOE CDIF. Yet the proposed 80 Mw thermal ITF project is likely to require as much as $200 million over several years. It is simply unnecessary and would needlessly stretch out program schedules and greatly increase program costs without any significant gain. Key MHD phenomena that are difficult to observe at a 50 Mw thermal scale will still be difficult to identify at 80 Mw thermal.

The utility industry in a study recently completed for the State of Montana Department of Natural Resources and Conservation outlines a set of performance requirements which must be met before the utility industry could, with reasonable expectation, proceed with commercialization of the MHD technology. An integrated system test at the 80 Mw thermal scale will simply not meet these rquirements. While some additional risks are involved in going from the present scale of testing to a facility on a scale of 350 Mw thermal (the 1983 MHD Forum's proposed approach), the resulting reduction in overall program costs and development time would jusfity these technical risks.

If the DOE view is that an intermediate scale integrated system test is needed to minimize government involvement programmatically and financially and yet reach a reasonable technical end to Federal government activity, the intermediate unit should still be configured and operated as a retrofit at an actual electric utility site. The size of that retrofit should perhaps be at some appropriate intermediate scale between the DOE proposed 80 Mw thermal (20 Mw electric) and the Forum's and utilities recommended 350 Mw thermal (120 Mw electric) size plant. Before deciding on the final size a more detailed analysis should be conducted relative to specific requirements at appropriate utility sites. From a scientific and engineering viewpoint this will allow the critical MHD phenomena to be studies in a long duration, slagging environment (which should be a major scientific objective of the Federal program) and yet be representative of a projected commercial plant environment. If the DOE proposed program objective is indeed to take the technology to a logical Federal conclusion (as stated in the FY 1985 DOE budget request), the successful operation of a cost shared integrated test facility by industry in a "real world" electric utility environment would be a minimum requirement.

The DOE fifty-fifty cost share was unilaterally proposed by DOE. This is an issue which must be jointly resolved between DOE and industry. That percentage cost share seems inappropriate for a technology at this early stage of engineering development, particularly in a government owned facility as proposed by DOE which has little potential for utilities to gain the necessary industrial operating experience. A more logical approach will provide a better vehicle for industrial financial participation and will attract greater industrial and utility interest.

Mr. Chairman, it is most unfortunate that whoever developed the DOE FY 1985 MHD plan did not take into consideration the strategy which was completed for the MHD Industrial Forum over several months in 1983 by a committee of distinguished representatives of the utility industry, its suppliers, the MHD development community and architect and engineering firms specializing in the construction of utility plants. In preparing the MHD Forum's strategy for commercialization, we took great care in selecting committee members who had considerable MHD expertise and extensive experience in developing and costing power plants for utilities. As a consequence I am confident that both strategy and cost estimates as they appear in the Forum strategy are the best available. You will also note that industry volunteered to assume thirty to forty percent of the cost of the retrofit program.

I might point out that the DOE plan before you also ignores the findings of its own study conducted by Gilbert Associates in compliance with the FY 1983 Continuing Resolution. The recent DOE Inspector General's report on the MHD program contradicts the Departments proposed FY 1985 MHD program approach. That report also pointed out policy level management problems at DOE contrary to Congressional direction while finding MHD program level management and technical progress were positive.

The MHD community has begun and will continue meeting with Assistant Secretary Vaughan and his representatives at his invitation in the coming weeks to work out a program on which the department and industry can agree. While we believe the Committee must understand the negative nature of the Department's proposed MHD program direction, we believe the proposed budget request of $17.8 million is a step in the right direction, and we are most positive towards the Assistant Secretary's desire to work together.

We would ask the Committee's indulgence to allow us to present further written testimony in late May as to the success of industry's discussions with DOE.

We appreciate this opportunity to present written testimony for the record and will be available to discuss the FY 1985 DOE MHD program budget at your request. Your continued support of the MHD program would be most appreciated.

STATEMENT OF
JACK M. SHERICK
PRESIDENT OF MSE, INC.
BUTTE, MONTANA

Mr. Chairman and Members of the Committee:

I am pleased to submit this testimony in favor of S.1278 which in reality is continued and increased support of magnetohydrodynamics (MHD) development. I heartily concur with the presentations of my colleagues that disclosed the advantages, benefits, and requirements necessary for the continued development of MHD -- the best of the advanced coal utilization technologies. In this testimony I will present:

1) The accomplishments and plans at the Department of Energy's Component Development and Integration Facility (CDIF) and how its operation directly supports MHD development.

2) How and why many foreign countries are pursuing MHD development, regardless of the involement and plans of the United States.

3) The brief results of a recent engineering assessment funded by the State of Montana (with abundant utility contribution) regarding the retrofit of an existing Montana Power Company coal-fired power plant with an MHD topping cycle.

4) Evidence that the MHD development program has already received appreciable private cost sharing.

Through these points I will show that considerable progress has been and is being made in the development of MHD, but the proposed funding level will slow, if not end, the engineering development of MHD.

DOE's CDIF in Butte, Montana is one of the key facilities that provides test data for "an orderly scale-up progression such that the national MHD program goals can be realized in the assigned program time frame." Construction of the facility was initiated in May 1976 and was completed in May 1981. The first test of the MHD combustor occurred in December 1980. Initial MHD electrical power generation was in April 1981, and MHD electrical power was supplied to the commercial electrical grid via an Electric Power Research Institute (EPRI) inverter for the first time in April 1982.

Over thirty-three hours of MHD electrical power generation have occurred at the CDIF, providing much insight and engineering data in the areas of large channel slagging phenomena, inverter/MHD channel coupling, analytical correlation of experimental results, channel durability, coal processing techniques, and many general operational, first-time experiences for an MHD test train of the 50 megawatt thermal size. Currently, the CDIF test area is being modified to accept the TRW 50 megawatt thermal, coal-fired combustor (CFC). This modification process also includes upgrading the nitrogen system, the coal system, and the AVCO MHD channel that will be used with the TRW CFC. The future CDIF test plan includes initial checkout of the CFC followed by MHD power generation tests that culminate in duration testing of hundreds of hours. These future tests will provide extensive data on generating MHD electrical power using coal, continuous slag removal/electrical isolation, MHD component durability/reliability, and general first-time operational information. CDIF milestones have been met on schedule and often under budget, but reduced DOE funding has drastically limited the number of new MHD components (combustors, channel, and superconducting magnet) that were originally scheduled for testing at the CDIF. The CFC (only the first stage) scheduled for delivery to the CDIF in June 1984 will be the first new DOE-provided MHD component in three years. However, even with this reduced funding, progress in developing the engineering data base required to advance the technology has been growing from the experience and data obtained at the CDIF.

Many people do not realize the international effort underway to commercialize MHD in more than one aspect. In the USSR, the technology is considered commercially viable using natural gas as the fuel. A commercial scale, natural gas-fired, 500 megawatt electrical (250 megawatts MHD) is under construction at the Ryazan Power Plant outside Moscow. At the High Temperature Institute (IVTAN) and in many of the USSR's ally countries (Poland, Hungary, Czechoslovakia, Romania, Bulgaria, and Yugoslavia) a major effort is continuing to identify and experimentally solve MHD power generation problems associated with using coal as a fuel rather than natural gas or oil. The USSR recognizes that they currently enjoy an abundance of natural gas, but the real future for MHD is its operation with coal. Engineers and scientists of China express these same sentiments regarding MHD's advantages coupled with the ability to use coal. The Chinese MHD program is growing rapidly and an information exchange agreement has been established between China and Mississippi State University. India has unveiled an active MHD program with a long-range emphasis on using coal as fuel (much of their early work was in cooperation with the USSR). Japan continues their MHD effort and generated MHD electrical power using oil and coal for the first time in the fall of 1983. They were able to meet stringent environmental standards with the addition of coal, which was a major concern. Australia has an MHD effort that hopefully will lead to additional marketing of their vast coal reserves. The Netherlands and Japan have closed-cycle MHD programs that are not as technically mature as open-cycle MHD, but may hold promise for specific MHD applications. Israel has a solar-powered, liquid-metal MHD program that is progressing well; this type of MHD has a rather specialized application. Italy is studying the feasibility of retrofitting an existing gas-fired power plant with an MHD topping cycle. In addition to these varied MHD applications worldwide, the USSR has a mature MHD-pulsed power generation program that is used for geophysical application and very probably military application.

Therefore, I'm saying that MHD in many parts of the world is regarded by technical and government people as a viable technology. A majority of the countries are starting to stress the application of MHD using coal, but innovation is occurring that will use MHD coupled with power intensive industry (e.g., the aluminum industry), as a solar/electrical power source in remote areas, and probably in military applications. To me, it is obvious we are losing our competitive edge in coal-fired, open-cycle MHD and have most likely been surpassed in the other applications of MHD; this is not a desirable position for the United States.

I would like to describe the results of the "Engineering Assessment Of An MHD Advanced Test System Retrofit" funded by the State of Montana's Department of Natural Resources and Conservation, showing their support for MHD. The assessment was accomplished in two phases. The first phase defined the performance requirements for an MHD Advanced Test System (ATS), formulated by contributed utility industry involvement, to ensure that the concerns of the user were taken into account. The Montana Power Company, in conjunction with the Edison Electric Institute MHD Task Force, developed these utility performance requirements for an MHD ATS. This information was submitted in report form to the Montana Department of Natural Resources and Conservation (DNRC) by the Montana Power Company.

The second phase of the assessment was to expand the MHD ATS performance requirements (established in the first phase) into functional, operational, and design requirements to be used for the follow-on step in an ATS program, e.g., the conceptual design of an MHD ATS. I want to emphasize that an ATS is not the commercialization of MHD. The ATS is the next scale-up step that provides the utility industry with a demonstration that commercialization of MHD, the final step, is a reasonable and technically sound step to take.

The second phase accomplishments were: (1) selection of a power plant for a site-specific analysis (the plant needed to be representative of plants nationwide amenable to an MHD retrofit); (2) definition of an appropriate MHD retrofit configuration for the selected power plant; (3) analysis of the retrofit configuration to predict the MHD power train and bottoming plant performance; (4) development of functional, operational, and design requirements for the retrofit configuration; (5) estimation of preliminary costs and schedules for design and construction of the MHD ATS; and (6) formulation of modifications to DOE's National MHD Development Program to reflect the MHD ATS concept. The preceeding information was documented in a two volume report which is available from the Montana Department of Natural Resources and Conservation in Helena, Montana.

I would like to summarize the results of the assessment. Two-hundred thirteen utilities nationwide were contacted to submit plants they considered amenable to an MHD retrofit and provide comments on the MHD ATS concept. Seven plants were submitted as potential candidates for an MHD ATS retrofit. The Montana Power Company's J. E. Corette power plant was selected and a reasonable MHD scale-up from the CDIF size was assessed to be 5:1 or a 250 megawatts thermal MHD test train. With this size MHD ATS retrofit, the plant's power output could be raised 29 percent or 163 ME_e to 210 MW_e (19 MW_e additional steam generation and 28 MW_e MHD generation). A simple, conservative retrofit configuration was chosen that also considered minimizing the funding requirements. A parallel steam-flow retrofit concept was analyzed and the performance of the MHD test train evaluated at the current state-of-the-art. The retrofit configuration chosen has a small efficiency penalty (less than one percent), but one must remember that this is a proof-of-concept plant and not a commercial MHD plant. The projected cost with a 20 percent contingency for such an MHD ATS retrofit was $187.3 million (1983 dollars) and the retrofit would be totally operational in approximately seven years. However, because of the uncertainty of high technology items such as the new components in the plant that are associated with the MHD process, a 30 percent confidence level was chosen as a worse case situation. This would project capital construction costs could be as high as $243.5 million.

Thus, already available is a $500,000 State of Montana/$250,000 utility contribution of an indepth, site specific assessment of what is involved in providing an integrated test facility at a utility site. The scale-up is reasonable and should adequately satisfy the questions posed by the utility industry and component manufacturers with regard to the final step -- a commercial MHD power plant or a commercially viable MHD retrofit. The large degree of interest in this study by the private sector leads me to believe that an MHD ATS of the size projected in the assessment would attract a reasonable level of cost sharing. It should be noted that S.1278 is an effort to enact just such a program as outlined in the assessment and Montana Power Company has indicated their support by offering either of two different power plants at which to perform such an MHD retrofit.

Cost sharing is a realistic part of commercializing new technologies and I would like to point out that utilities, state governments, and industry have invested over 50 million dollars in the past ten years or more (Attachment I). The Southern California Edison Company continues to privately investigate the MHD retrofit/coal conversion options for its oil-fired power plants. The Electric Power Research Institute still supports its investment in the MHD inverter at the CDIF and is also funding current consolidation studies through three different groups. The developmental risk is currently too great for the utility industry/equipment suppliers to assume total responsibility for MHD development beyond the current proposed DOE involvement level. Government participation is required in an integrated test and the concept in S.1278 is the level and scale of participation needed.

I believe I have shown that progress on the engineering data base needed for MHD development is occurring and the CDIF is a major contributor to this progress. The program continues to meet its milestones, but the funding situation is starting to impact the rate of progress while foreign development continues at an accelerated pace. Cost sharing in the development of MHD has occurred and must be recognized. Significant work remains to establish the needed engineering data base, but a focus is needed, such as S.1278 that provides a realistic final role of the government in MHD.

I appreciate the opportunity to submit this written testimony for the record and hope it conveys the attributes of MHD. I strongly feel that this technology can play a key role in helping to solve our nation's energy and environmental challenges.

ATTACHMENT I

INDUSTRY AND STATE GOVERNMENT INVESTMENT IN MHD

To date, industry and state governments have invested over $50 million in research and studies on the MHD technology. These investments are summarized below:

I. Utility Industry

A. Electric Power Research Institute (EPRI)

Since 1974 EPRI has funded $8-$10 million in various studies on MHD. In addition, EPRI funded the design, construction and installation of the $2 million inverter at the CDIF. EPRI has budgeted $1.5 million for MHD over the next five years.

B. Edison Electric Institute

The 21 member EEI Task Force and MHD (Utilities MHD Users Group) has been meeting twice yearly on MHD for the past three years. In addition, the Task Force members have participated at their own expense in the studies sponsored by the State of Montana DNRC. Contribution of engineering services and travel by EEI Task Force members and the utilities is about $250,000.

C. Southern California Edison

SCE has funded $600,000 - $700,000 of MHD work during the past five years. In addition, an estimated $350,000 will be beginning in FY-84.

D. Montana Power Company

The MPC has actively supported the MHD technology for a number of years. MPC has submitted proposals to the DOE for a cooperative project at their planned Salem Plant and is one of the utilities that would be very receptive to participating in the MHD Industrial Forum concept.

E. American Electric Power Services Co.

In the 1960's, AEP supported approximately $1 million of MHD work.

II. State Governments

A. The State of Montana through its Department of Natural Resources and Conservation (DNRC) has funded $500,000 to conduct an engineering assessment of retrofitting MHD. In addition, utility contribution to this project as noted in I.B. has been in the order of $250,000.

B. State of Tennessee

The State of Tennessee provided a $2.2 million building to the University of Tennessee Space Institute of which one-half is dedicated to MHD research.

C. Others

Several states other than Montana have expressed interest in supporting coal technologies. Specifically, the State of Alaska has been considering funding studies in MHD application in Alaska.

III. Industry

A. Reynolds Metals Company

Over the 10 year period, starting in the mid 1960's, Reynolds Metal invested approximately $5 to $6 million in MHD research.

B. TRW Incorporated

To date, TRW has invested about $8 million in MHD including about $3 million in their MHD combustor test facility.

C. AVCO

AVCO has been involved in MHD research for over 25 years. During the 1960 to 1970 time period, AVCO with a group of utilities, invested over $10 million in MHD research.

D. Westinghouse

Westinghouse has been involved in MHD Research since 1939 and has invested $15-$20 million in research on the technology since then.

E. General Electric

In the 1950-1960 time period, General Electric invested $1-$2 million in MHD research.

F. University of Tennessee Space Institute

UTSI has invested about $500,000 in facilities for MHD research plus, as noted in II.B., the State of Tennessee provided a $2.2 million building about one-half of which is dedicated to MHD.

The University of Tennessee Space Institute
TULLAHOMA TENNESSEE

COAL FIRED FLOW FACILITY SENATE TESTIMONY

April 9, 1984

Y.C.L. Susan Wu

UTSI Publication No. E02-0115-007-84

On

The 'National Coal Science, Technology,
and Engineering Act of 1983' (S. 1925)

and

The 'Magnetohydrodynamics Reseach, Development
and Demonstration Policy Act' (S. 1278)

Presented to the

Subcommittee on Energy Research and Development
Senate Energy and National Resources Committee

Mr. Chairman and Members of the Subcommittee:

I am Y. C. L. Susan Wu, Professor of Aerospace Engineering and Administrator of the Energy Conversion R&D Programs at The University of Tennessee Space Institute (UTSI), Tullahoma, Tennessee. It is indeed a great honor for me to have this opportunity to submit my testimony in support of the two bills - S1278 and S1925.

Much persuasive deliberation has been given in the past, and there will be more in the future on the "whys" we should rely more heavily on coal for our energy needs. For this reason I will make my discussion on two other issues, one is on the environmental advantages of MHD, and the other a brief description of the DOE Coal-Fired Flow Facility (CFFF) which can support a broader based testing program to enhance coal utilization, especially in supporting the "National Coal Science, Technology, and Engineering Development Act of 1983".

MHD power generation is based on the interaction of electromagnetic fields with a moving plasma. For open cycle MHD, the plasma is produced by combustion of coal (or other fuel) with the aid of seed, typically potassium carbonate, to enhance the electrical conductivity. The MHD combustor temperature reaches 5000°F and pressures typically reach 5 atm. or more. The plasma expands through the MHD channel, encountering the electromagnetic fields, and generates electricity, much like a high pressure gas or steam expands through turbine blades to produce mechanical work. After the electrical energy is extracted from the plasma, the hot gas (typically 3500°F) still contains a great deal of energy which can be used to generate additional electricity in a steam plant (over 50% of the power is generated by the steam cycle in an MHD/steam plant).

The bottoming steam plant is considerably different from the conventional steam plant, due to the addition of potassium seed and different temperature history of the gas. For this reason the steam cycle is called the Heat Recovery/Seed Recovery System (HRSR). The HRSR not only generates additional electricity, but also performs the environmental control functions.

The Coal-Fired Flow Facility (CFFF) is located on the campus of The University of Tennessee Space Institute. Figure 1 shows the CFFF, which is the only facility that can test the HRSR system for coal. In the past two years, important data on NO_x and SO_2 were obtained. We are in the process of installing a superheater, air heater, and a baghouse this fiscal year and installing an electrostatic precipitator next fiscal year to collect particulate emission data. I am looking forward to reporting these results to you when they become available.

Potassium (K) seed provides the free electrons necessary to conduct electricity in the MHD topping cycle; however, in the bottoming cycle, it acts as a scrubbing agent to absorb SO_2 and form K_2SO_4, which can be captured by particulate removal methods. For MHD, 1% K by weight in the total flow is needed to provide adequate electrical conductivity. This amount of K can clean 4% sulphur coal. If higher sulphur coal is used, one simply needs to add more potassium. Figure 2 shows the SO_2 reduction results obtained at the CFFF.

The nitrogen oxides control is achieved through staged combustion. Figure 3 shows the data obtained over a wide range of conditions. For primary stoichiometries favorable to electrical conductivities, we can comfortably comply with the New Source Performance Standards (NSPS). A calculated emission level of an early commercial MHD plant (AVCO CSPEC) is shown on Figure 4 and indicates that NO_x emission is substantially below NSPS.

Preliminary data on ash deposition represents the integrated test of environmental control and heat recovery system which is monitored by the overall heat conductance of boiler tubes. Figure 5 is the overall heat transfer to the heat exchanger while the gas side conditions are stable. This figure represents the rate of deposition which reached a relatively stable overall conductance nearly 4 hours after coal seeded with potassium firing began.

There are many other technologies that can also achieve a low level of emissions similar to MHD. Indeed they should be pursued, as many of these are much nearer term than MHD. However, MHD has the potential of achieving significantly higher conversion efficiency from coal pile to busbar. Higher efficiency not only reduces the fuel cost and saves our precious natural resources, but also lowers the relative emissions, transportation cost of raw coal, and the cost of solid waste disposal. Table 1 summarizes the efficiencies and cost of electricity for several different size MHD plants. For example, with a conventional steam plant at 33% efficiency compared to an early MHD plant at 41%, the decrease in fuel per kw-hr is 19.5%, a very sizable decrease! For a mature MHD plant, the decrease of fuel consumption could be as high as 40% per kw-hr. In fact, there is no method to reduce CO_2 emissions unless we burn less hydrocarbon fuels; increasing efficiency will reduce the amount of fuel that needs to be burned, per kw-hr.

DOE has two facilities for MHD, one in Tennessee, the CFFF with a capacity of $28MW_t$, and one in Montana, the Component Development Integration Facility (CDIF), rated at $50MW_t$. The two facilities represent a logical scale-up in the process of technology development as well as addressing different technical issues (Table 2). Currently, both facilities are in operation and important data are being produced. It is crucial that these activities be continued. The DOE Assistant Secretary for Fossil Energy, Mr. Vaughan, and his staff are meeting with the MHD Industrial Forum and Edison Electric Institute's MHD Task Force to discuss an MHD program. This is an extremely positive move toward developing this potentially important technology, to be ready for commercialization. We applaud this new initiative and also ask Congress to lend its support to this endeavor.

The CFFF has three test bays. Currently only Bay 1 (designated as Low Mass Flow) is used for MHD testing. It is rated at 30 MBtu/hr for conventional applications (higher rating for MHD due to oxygen enrichment). Figure 6 shows the schematic of the downstream of the CFFF, which contains superheater, air heater, baghouse, electrostatic precipitator, and venturi-cyclone for intermediate cleaning of the gas stream. Bay 2 was initially designed for the High Mass Flow MHD testing which is rated at 150 MBtu/hr for conventional applications. It can be used for large burner tests. Bay 3 was intended for other DOE use.

Figure 7 shows the environmental monitoring sites of air, water, and terrestrial ecology of the CFFF. Data have been collected on the environment since 1979. A well documented baseline has been in existance since then. The facility is flexible and can be adapted easily to carry out integrated testing of environmental control and heat recovery systems. Such a facility, if built today, will cost more than $80M and at least five years to construct and checked out before data can be obtained. I would like to take this opportunity to make this distinguished subcommittee aware of the CFFF for broad based testing in addition to MHD. The existence and availability of the CFFF can contribute and accelerate the technology development that is contained in the bill introduced by the Honorable Senator Byrd.

In conclusion, I strongly support the two bills (S1278 and S1925) that are being considered today since they provide the necessary resources and focus toward better utilization of our abundant fuel - COAL.

Thank you very much for giving me this opportunity to present my views.

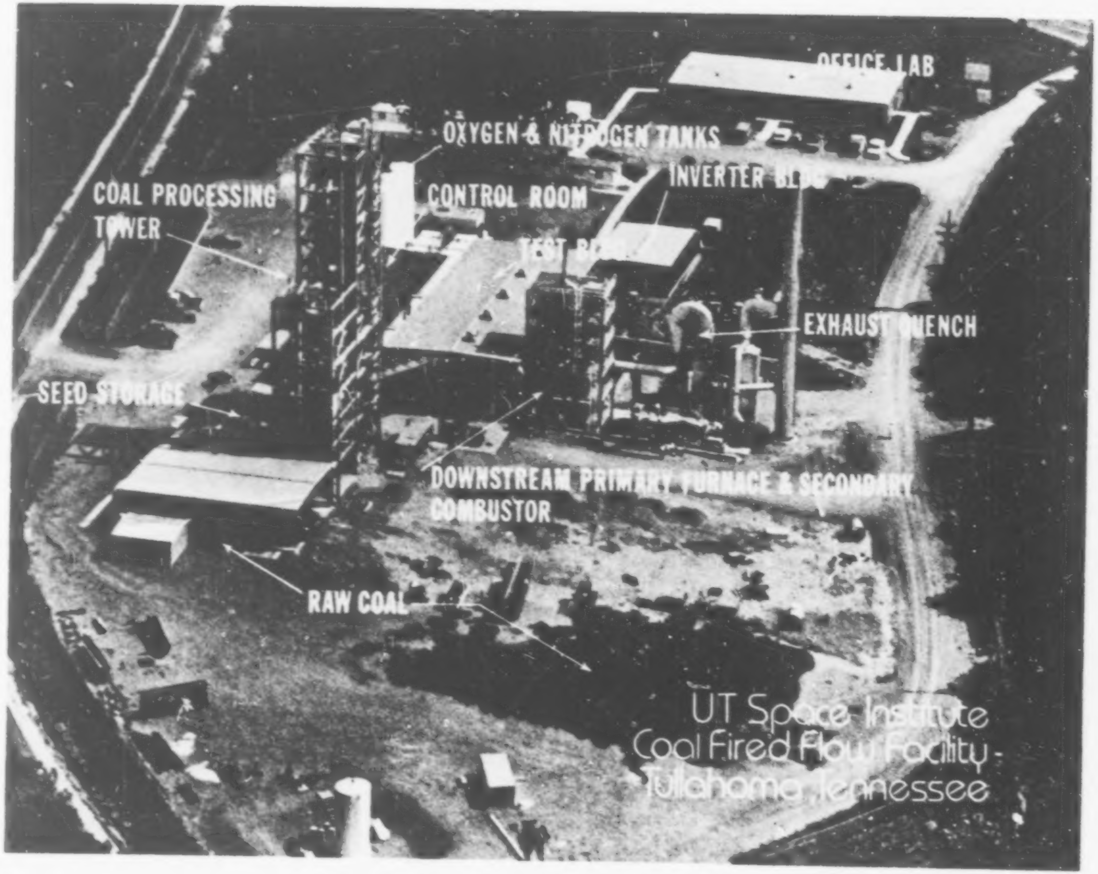
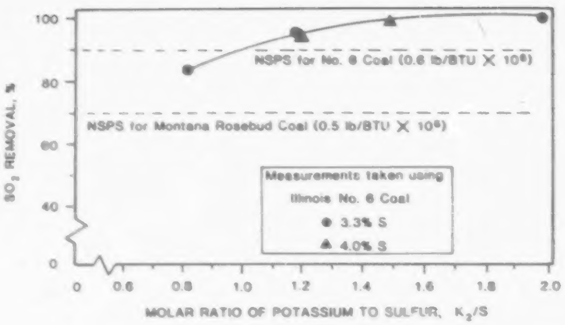
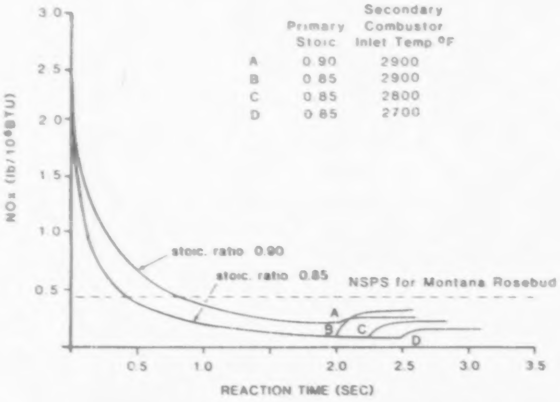

OFFICE LAB
OXYGEN & NITROGEN TANKS
INVERTER BLDG
COAL PROCESSING TOWER
CONTROL ROOM
TEST BLDG
EXHAUST QUENCH
SEED STORAGE
DOWNSTREAM PRIMARY FURNACE & SECONDARY COMBUSTOR
RAW COAL
UT Space Institute
Coal Fired Flow Facility -
Tullahoma, Tennessee

Figure 1 The Coal Fired Flow Facility (CFFF)



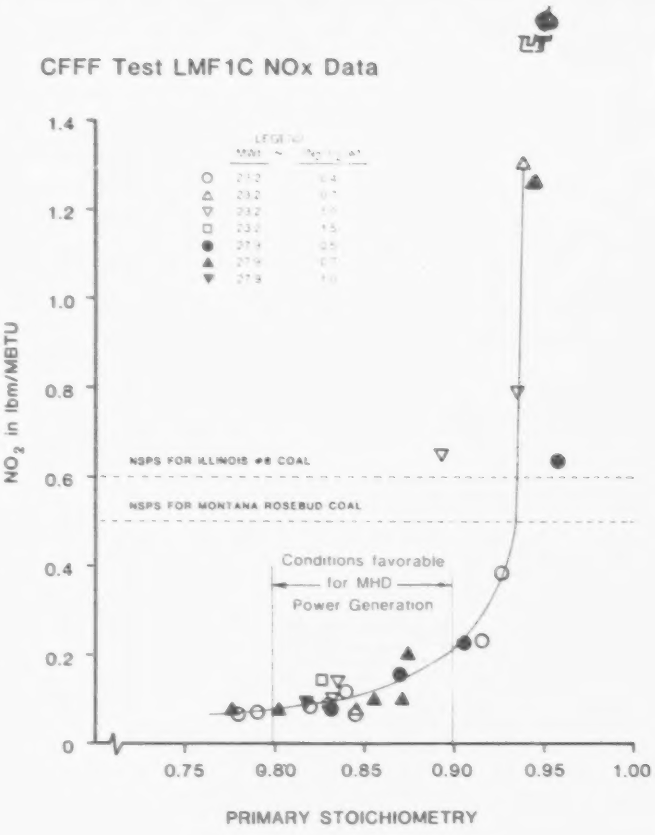
Sulfur Removal Efficiency By Potassium Sorbent in an MHD System

Figure 2



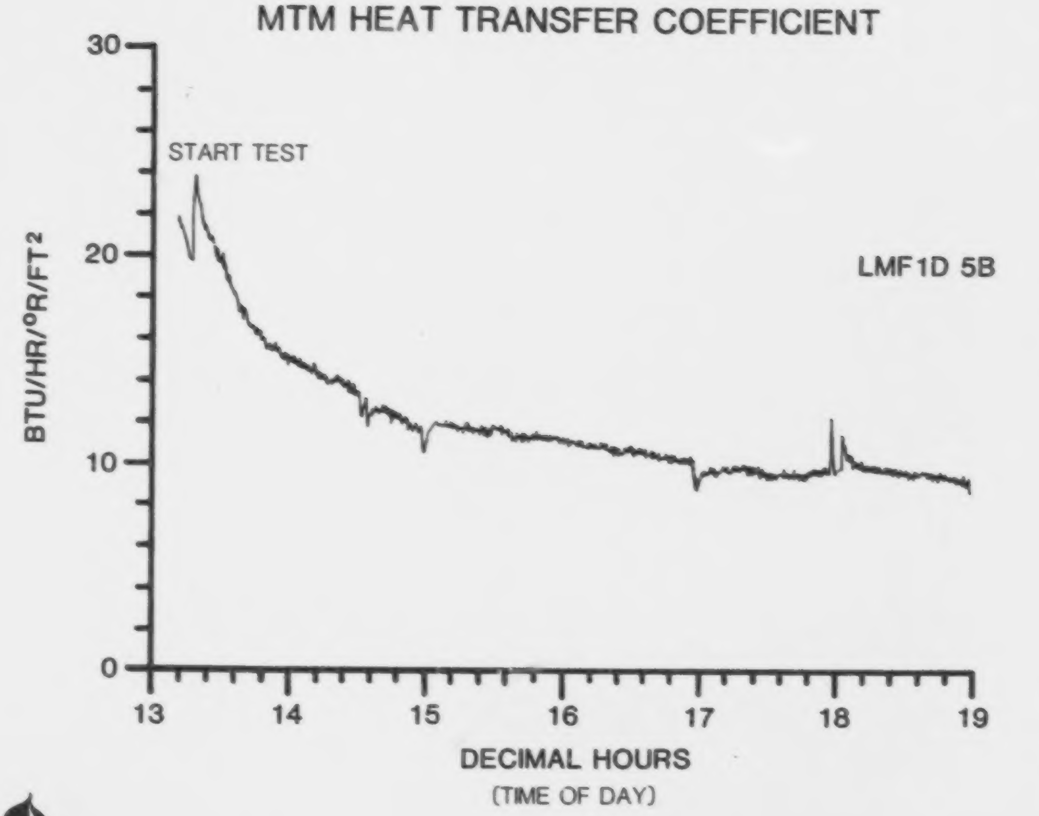
Calculated NOx vs Reaction Time Using (AERL) CSPEC MHD Plant

Figure 4



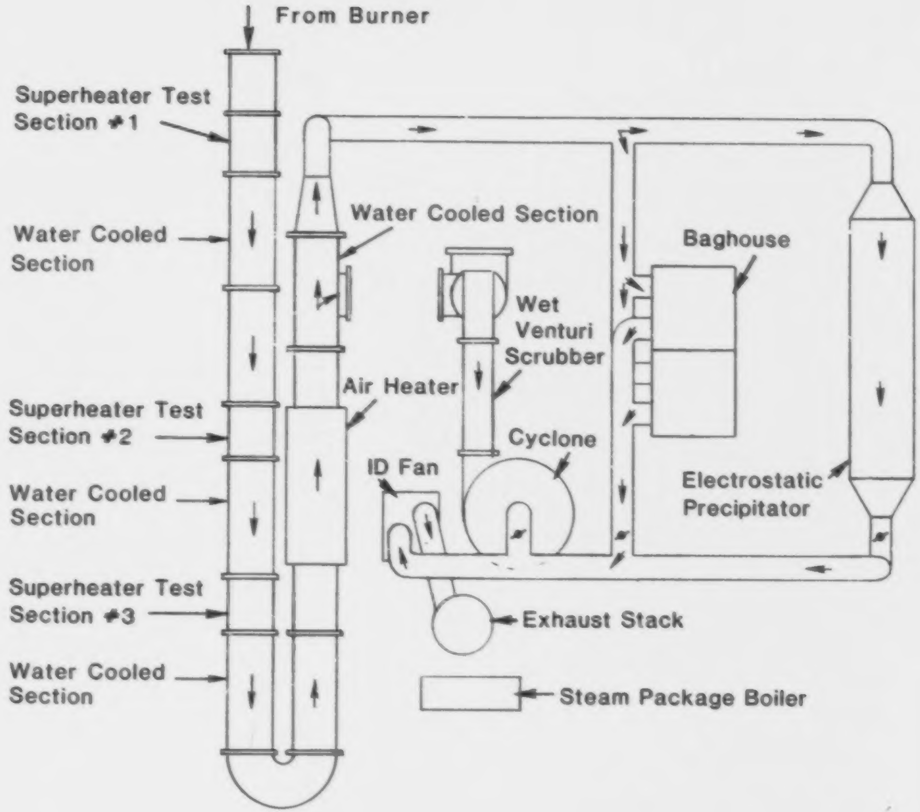
NOx vs Primary Stoichiometry

Figure 3

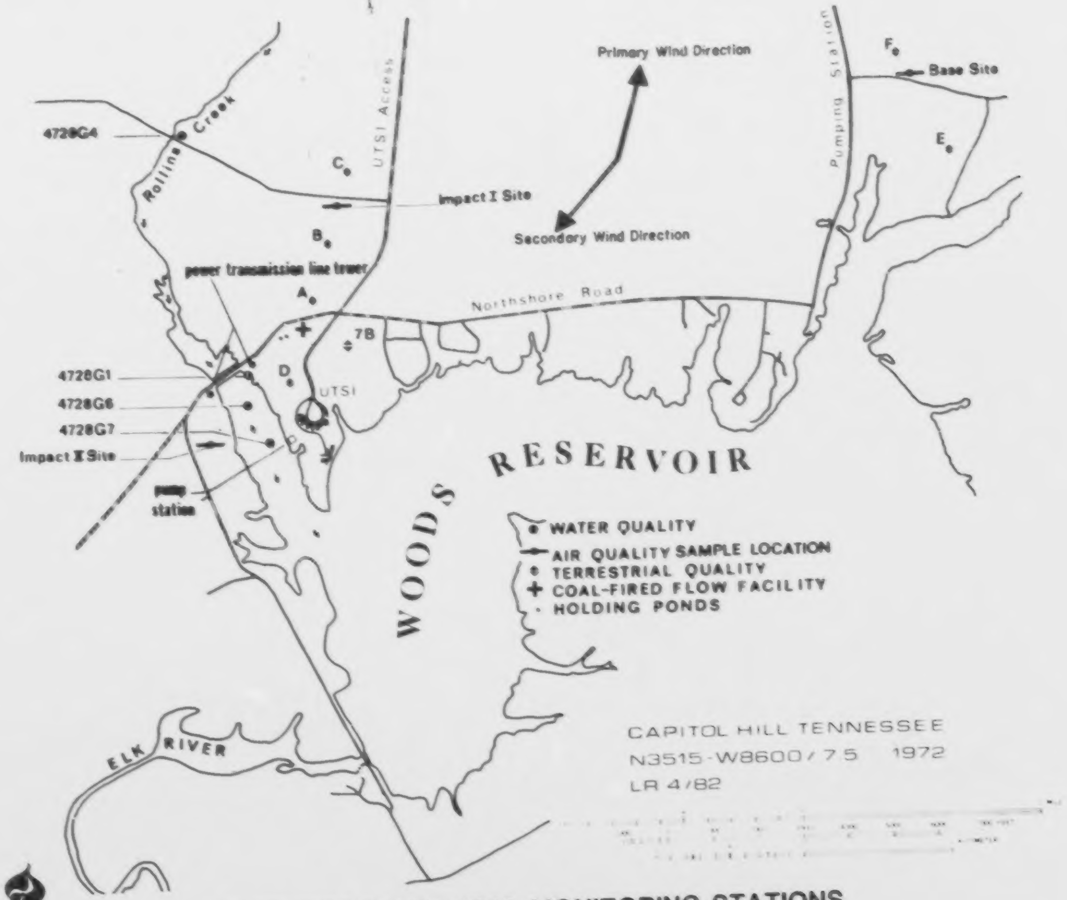


Overall Heat Transfer Coefficients on Boiler Tubes after Coal Firing

Figure 5


From Burner
Superheater Test Section #1
Water Cooled Section
Superheater Test Section #2
Water Cooled Section
Superheater Test Section #3
Water Cooled Section
Water Cooled Section
Air Heater
ID Fan
Wet Venturi Scrubber
Cyclone
Baghouse
Electrostatic Precipitator
Exhaust Stack
Steam Package Boiler

CFFF Downstream Configuration
Figure 6


Primary Wind Direction
Secondary Wind Direction
Fe
Base Site
Ee
Pumping Station
UTSI Access
Ce
Impact I Site
Be
4728G4
Rollins Creek
power transmission line tower
Ae
Northshore Road
7B
De
UTSI
4728G1
4728G6
4728G7
Impact II Site
pump station
RESERVOIR
WOODS
ELK RIVER
WATER QUALITY
AIR QUALITY SAMPLE LOCATION
TERRESTRIAL QUALITY
COAL-FIRED FLOW FACILITY
HOLDING PONDS
CAPITOL HILL TENNESSEE
N3515-W8600/7.5 1972
LR 4/82

CFFF ENVIRONMENTAL MONITORING STATIONS
Figure 7

MHD PLANT STUDIES:
A COMPARATIVE OVERVIEW

PARAMETER	MATURE PLANT CONFIGURATIONS			EARLY COMMERCIAL PLANT CONFIGURATIONS			CONVENTIONAL REFERENCE COAL PLANT		GAS FIRED MHD PLANT
	ECAS/GE	EPRI/AF664	GAI/ECAS* Update	EPRI/W**	AVCO/ C.T Main (PSPEC)	AVCO/ C.T Main (CSPEC)	ECAS*** (1979 NSPS)	NASA Burns & Roe	USSR--U-500 (Under Construction)
Coal Pile To Busbar Plant Efficiency (%)	48.3	48.3	54	41.7	43.4	43.9	32.3	34.4	60%
Coal Pile To Busbar Plant Capital Cost ($/KWe)	591.6	591.6	600	945	709.7	711.3	730.8	674.7	Reported To Be Below Conventional Power Plants
Levelized Cost Of Electricity (mills/kW-hr)	37.7	37.7	35	48.2	41.9	42.9	51.9	48.5	Reported To Be Well Below Conventional Plant
Stack Gas Temperature	260	250	260	260	250	250	250	175	
Relative Unit Size	2	2	2	1	1	1	1	1	

* Parametric consideration of the ECAS plant reflecting advances in component technology--e.g., replacement of the inefficient PERC seed regeneration process used in ECAS with a more energy efficient Formate or Engle-Precht process and a higher temperature air heater. (Other GAI parametric MHD plant studies showed efficiencies approaching 60%).

** The parameters for the oxygen enriched plant configuration are shown--modified in accordance with the "advancements" described in EPRI report AF 640-1, utilizing a more efficient commercially available oxygen plant and fuller utilization of regenerative feedwater heating in the steam bottoming cycle.

*** ECAS steam coal plant modified to comply with EPA 1979 NSPS (DOE/NASA/0167-2, August 1980)

Table 1

CONTRACTOR SITES OR FACILITIES AT WHICH EXPERIMENTAL ISSUES ARE ADDRESSED

ISSUES ADDRESSED	THERMAL POWER LEVEL				
	10-30 MW_t	50-100 MW_t	250 MW_t	300 MW_t	1000 MW_t
1. Thermodynamic Performance - MHD	CFFF AVCO UTSI U-25B**	CDIF	AEDC MARK V* LORHO* U-25**	Retrofit	U-500***
2. Thermodynamic Performance MHD Plant	--	--	U-25**	Retrofit	U-500***
3. Equipment Life/Durability	CFFF AVCO	CDIF	U-25**	Retrofit	U-500***
4. Scalability	CFFF AVCO UTSI	CDIF	AEDC U-25 MARK V* LORHO*	Retrofit	U-500***
5. Seed Recovery/ Heat Recovery	CFFF	--	U-25**	Retrofit	U-500***
6. Emissions Control	CFFF UTSI	--	U-25**	Retrofit	U-500***
7. Coal Combustor and Coal Feed Performance	CFFF AVCO UTSI TRW****	CDIF	--	Retrofit	
8. Electrical Power Take Off & Inversion	AVCO	CDIF	U-25**	Retrofit	U-500***
9. MHD/Steam Plant Operability	CFFF	--	U-25**	Retrofit	U-500***
10. Operation and Maintenance Costs	--	--	U-25**	Retrofit	U-500***
11. Capital Cost	--	--	U-25**	Retrofit	U-500***

* The 400 MW_t MARK V tests and the 250 MW_t LORHO tests were completed in the mid 1960's but the test data still contribute to the relevant issues.

** Existing U.S.S.R. facilities to which U.S. has access (currently operating on natural gas).

*** Planned U.S.S.R. gas-fired commercial demonstration plant expected to be on line by the mid-1980s.

**** TRW/MHD test facility at Capistrano was constructed by TRW with corporate funds.

Table 2

Senator **Melcher**. Thank you, Mr. Irving.

Mr. Katlic, your testimony on behalf of the American Mining Congress is very good. But I want to say also your very pertinent suggestions for S. 1925 and the details that you have put in your testimony regarding various sections of it will be most helpful to this committee. Thank you very much for doing so.

I want to tell Mr. Podolny that I am personally delighted, and I think I'm speaking on behalf of all of this committee, about your work on fuel cell operations. The testimony you have presented, at least for me, is encouraging and hopeful. I agree with your points and I think they're needed. I think the participation of the Federal Government is absolutely essential in order to bring this technology into commercial use.

Now, Joe, your testimony is very helpful. Montana Power is one of the private companies that has been a pioneer in MHD work. Your personal commitment to it has brought it on much farther than would otherwise be the case if we hadn't had your personal interest and that of the Montana Power Co.

I think we have been wasting time in the past several years. We started out in a more vigorous way in the mid-1970's and the effort dwindled to relative inactivity.

However, if we can pass S. 1278 for an MHD program, then I think we will make real progress.

The points you brought out that hadn't been mentioned, savings in transportation, for instance, because of greater efficiency, works both ways, of course. Not only do you have a need for transportation, but you save energy in the transportation of coal.

And, of course, the conservation point is one we can't ever forget. I think you're correct. I think that the U.S. Government's lack of attention and the zero budgeting during the past 3 years has pulled a blanket of gloom over our role in continuing with MHD as part of the international effort to make MHD practical.

Granted, the Russian's success with natural gas shouldn't be forgotten. Joe, I know that you and Mr. Irving have not forgotten their success. I find it appalling that the United States can't meet an obvious challenge with MHD and other coal research and development programs.

We sent the space shuttle to outer space. And when President Kennedy laid down the challenge to explore the Moon in the early 1960's, all the country found it easy—it might have sounded fuzzy when the President laid down that challenge, to meet that challenge. And we continue to meet challenges in engineering and technology. This makes it a rather shameful past decade that we have not advanced further in research and development on the utilization of coal. I hope we can correct this beginning this year.

I am encouraged by Secretary Hodel, and Assistant Secretary Vaughan up to a point. I'm encouraged but it's a small plateau. I don't know what their constraints are. Budget constraints are one thing, Office of Management and Budget cracking the whip is another thing, and sometimes it's hard to discern what the true concerns of the Cabinet members are. But, nevertheless, we have gotten some encouragement this year. I hope we can develop that encouragement into some important work in coal research and development.

Now, Mr. Irving, the MHD community, in particular the MHD industrial forum, the membership of which reads like a history of who's who in MHD, ought to add—whether he likes it or not, United Technologies and Bill Podolny onto that masthead so that we don't lose track of him.

Mr. **McElwain**. Senator, I make one point in my written statement that I think you have mentioned; and that is, if we don't proceed vigorously with MHD, I think what we will see happening is that we will be buying this technology and hardware from foreign sources rather than developing it here ourselves. And I think we don't want to have that happen if we can keep it from happening. It's one of the problems that we have now with our balance of payments, and I think we ought to vigorously be the ones that develop the technology and not leave it to other countries to do so.

Senator **Melcher**. I think you're absolutely correct.

This testimony today is the beginning of a fresh state in research and development on coal. And I will be very interested in the meeting that Secretary Vaughan is concerning on Thursday regarding MHD and the private sector. I hope that that meeting will result in recommendations for my bill on MHD.

But let me assure all of you, I'm interested in all phases of coal research and development.

I want to thank you all for your testimony. It's very much appreciated.

The hearing will stand adjourned.

[Whereupon, at 1:05 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

Senate Sub. on Energy
and Research Development
Asked by Sen. Domenici
Hearing of April 9, 1984

Question 1: The Department is proposing a program to initiate design and engineering development of an integrated coal-fired MHD plant at the 80 MW thermal level. Would the Department provide us with an overview of the technical areas concerning this project for the record?

Answer: The Department is proposing a program targeted at long-duration testing of a 50 MW(t) integrated MHD topping cycle, a 28 MW(t) integrated MHD bottoming cycle, and proof-of-concept testing of a seed regeneration system. The topping cycle tests will be conducted at the Component Development and Integration Facility (CDIF) in Butte, Montana. The bottoming cycle tests will be conducted at the Coal Fired Flow Facility (CFFF) in Tullahoma, Tennessee. The seed regeneration work will include bench-scale studies and proof-of-concept testing culminating in the development of a fully integrated, over-the-fence system, at a site to be determined by a competitive selection process. The proposed program, including an overview of technical areas of concern, is described in the enclosure titled "Coal Fired Magnetohydrodynamics Systems, Preliminary Transition and Program Plan" which was transmitted to the Congress on June 6, 1984.

An 80 MW(t) option was tabled as a strawman in a public meeting held in February 1984. This option was discarded as a result of inputs from the public meetings and preliminary conceptual design analyses of three integrated systems options, viz., 50 MW(t), 80 MW(t), and a 50 MW(t) (approximately 50 MW(e) from topping cycle) retrofit. There is substantial agreement that additional work needs to be done prior to proceeding with a large, fully integrated system. There is also agreement that the 50 MW(t) and 80 MW(t) fully integrated systems options offer no significant advantages over testing at the scales of the CDIF and CFFF.

COAL FIRED MHD SYSTEMS

PRELIMINARY TRANSITION AND PROGRAM PLAN

Overview

The Department of Energy (DOE) has in close consultation with the private sector, undertaken to realign the national MHD program. This paper outlines DOE's views on how the national program should proceed. The historic program which focused on subsystems development will be redirected to a multiyear program targeted on the achievement of proof-of-concept (POC) testing. Following the successful completion of the POC tests, the next logical MHD development step would be a fully integrated, coal fired, MHD retrofit.

The key components of the new program include:

- The design, construction, and operation of: (1) an integrated topping cycle, (i.e., an MHD power train), (2) an integrated bottoming cycle (i.e., a heat recovery/seed recovery subsystem) and (3) a seed regeneration system. These systems/subsystems will provide proof-of-concepts which are critical to the advancement of the technology to the MHD retrofit stage.
- Baseline subsystems development efforts to acquire the knowledge necessary to proceed with the integrated test facilities and the seed regeneration system.

The POC activities will proceed on concurrent, interrelated paths in a plan that will make optimum use of existing components and facilities.

The proposed program includes a flexible, cost-sharing arrangement designed to elicit a commitment from the private sector in the integrated systems and subsystems. Discussions with industry pertaining to cost-sharing were initiated in early February 1984. Preliminary indications suggest that the private sector may be willing to offer some cost sharing. The amount of cost-sharing will influence the pace of the program.

Assuming that there is adequate cost-sharing and subject to the availability of Congressionally appropriated funds, the new program will be initiated in FY 1985.

A conceptual design of the MHD retrofit system will be started in FY 1985 concurrently with the POC activities. The long duration POC testing of the topping and bottoming cycles will commence in FY 1987. Bench scale seed regeneration work will be initiated in FY 1985, leading to the design, construction and operation of a POC seed regeneration system by the late 1980s.

If the topping and bottoming cycle POC tests described earlier are successful, the next logical step would be the preliminary design (Title I) of the MHD retrofit in FY 1987 and with the detailed design (Title II) in late FY 1987 or early FY 1988. It is expected that at this stage the program would become largely a private sector responsibility with DOE's role limited to providing technical advise and possibly some funding support, depending upon its R&D benefits. In any event, it is premature to make any commitment technically to proceeding with the detailed design and construction of a retrofit project pending results of the POC. These results are not expected until 1987 or 1988.

The total program cost through the POC and conceptual design of an MHD retrofit, including private sector cost-sharing, is estimated to be approximately $150 million. The cost of the MHD retrofit will depend on the final design, configuration and site specific factors associated with the retrofit.

The FY 1984 program is directed towards the acquisition of data on the performance and operation of major subsystems. These activities will contribute significantly to the success of the integrated POC activities. Accordingly, the available FY 1984 funds will be focused to ensure the early completion of key activities.

Background

MHD is the highest temperature heat engine under development within Fossil Energy, hence it has the highest theoretical systems efficiency of any heat engine. However, it is the least mature technically and has the highest cost and longest lead time for ultimate development. The operating principle involves the direct combustion of coal to yield an electrically conductive gas which is then directly converted to electrical power when passed through a magnetic field. Afterwards, the high temperature gas is driven through a boiler to raise steam and generate additional electric power. The high performance (efficiency) potential of MHD power systems could permit its future utilization in electric utility systems. The high temperatures of the MHD combustor also provides the potential for the direct burning of any coal, regardless of its heating value and contaminant content. Environmentally, MHD also offers the advantage that most of the sulfur contained in the coal is removed by the MHD process.

The MHD program has reached a critical decision point; the technology is ready for integrated proof-of-concept system/subsystem tests. It is now time to focus the program on the least-cost, shortest development time path to establish the technology base for MHD power systems so that the private sector can subsequently commercialize the technology.

The technical status of MHD technology has recently been evaluated by Westinghouse, General Electric, Gilbert Associates, Inc., and the Argonne National Laboratory. Their conclusions as to the present technical status of key MHD components and what is required to bring them to a state of technical readiness sufficient for subsequent private sector commercialization include the following:

- The coal preparation and feeding subsystem does not represent a major technical issue. Nevertheless, scaleup, integration with MHD systems, electrical isolation and durability must be demonstrated.
- In the seed subsystem, preparation and feeding are not major technical issues but integration with MHD systems and durability must be demonstrated.
- The oxygen plant is considered commercially available and is not a major technical issue.
- Coal combustor development is considered a key technical issue in that scaleup, performance, and durability all remain to be demonstrated.
- Nozzle development is not a major technical issue. It is considered within the current state-of-the-art but must be integrated with MHD.
- Channel development is considered a key technical issue. Scaleup, long-term performance, and durability, all remain to be demonstrated.

- Diffuser development is not considered a major technical issue. Scaleup and integration with MHD must be demonstrated, however, particularly with regard to channel replacement.
- Inverter development is a moderate technical issue in that the current consolidation and control networks must still be developed and demonstrated.
- Superconducting magnet development is not considered a major technical issue but field constructability and integration with an MHD channel remain to be demonstrated.
- Emission control for MHD is not considered a major technical issue. However, scaleup and demonstration under actual MHD integrated system conditions remain to be undertaken.
- Development of the waste heat boiler, superheater, and low temperature oxidant preheater is considered a key technical issue. No large-scale testing or integration with MHD has yet been undertaken.
- Seed recovery and regeneration are considered key technical issues. Seed recovery has not yet been demonstrated in an integrated system and no process development has been undertaken.
- A high temperature air heater is not required for the early-commercial MHD powerplant concept.
- Economizer and low temperature air heater development are not major technical issues for MHD. These subsystems are already in use in full size powerplants.

While a number of technical issues remain, as described above, the primary uncertainties are:

- Downstream chemistry (seed recovery, seed regeneration, and related issues).
- Large-scale, long-duration, coal-fired, integrated system operation.
- Long duration coal combustor performance and scaling effects. Also more work is needed on channel durability and performance at high interaction levels.

It is estimated that it will take approximately 3 years to develop the necessary design information for the key MHD components for the MHD retrofit. Development of the seed regeneration subsystem data will probably require an additional year or two, i.e., 3-5 years.

DOE has developed a proposed program to serve as the basis of discussions with the Congress and the private-sector pursuant to redirecting the MHD program. The elements of the proposal and a preliminary transition plan are discussed in the remainder of this document.

Preliminary Transition Plan

The FY 1985 funding will be targeted on bringing the individual components and subsystems to comparable levels of technical maturity. Contractors' activities will primarily focus upon hardware development and testing to produce hardware for long duration testing at the integrated facilities. Hardware and subsystem tests will be continuations of efforts in progress under the FY 1984 program and will make maximum use of existing contractors' hardware and facilities.

It should be recognized that a detailed transition plan cannot be produced at this time because of the preliminary nature of the present program plan. The final program development, planning and implementation must take into consideration that the program will be a cost-shared venture in which the paying parties will expect to exercise a voice proportionate to their contributions. The final program will also be influenced by negotiations on cost-sharing and other program aspects.

Proposed Approach

The POC test facilities comprise two integrated subsystems, an MHD topping cycle and a steam bottoming cycle. The overall topping cycle layout is prototypical of early commercial plant design in that intermediate-temperature (1200 F), oxygen enriched air would be used as the oxidizer (fully developed and more efficient MHD plants are expected to employ high temperature (2900 F) air as the oxidizer).

As presently contemplated, the MHD topping cycle would be operated with the combustor at approximately 6 atmospheres and electrically isolated. The topping cycle would be capable of being operated continuously for extended periods (100 to 1000 hours) between shutdown. The MHD generator would be operated supersonically utilizing a superconducting magnet capable of continuous operation at a magnetic field strength up to 4.5 Tesla and all power conditioning electronics necessary to optimally interface the channel with the inverter components.

The heat recovery and seed recovery (HRSR) subsystem would incorporate critical elements necessary for the simulation of the MHD steam bottoming cycle. Specifically, the HRSR would include the hardware necessary for steam raising, seed, ash and slag collection, seed recovery from slag/ash mixtures, environmental effluent control, and ancillary components.

Work on the development of seed regeneration subsystems has lagged that of other MHD developmental efforts. As a result, it would not likely be possible to specify the regeneration process requirements in a time-scale compatible with their integration into the detailed HRSR system design. Therefore, the seed regeneration subsystem will be considered independent of the HRSR subsystem; this approach will lead to more flexible operation of the seed regeneration system and will not result in the loss of vital process data. Present preliminary plans include the conduct of bench scale tests followed by the design, construction, and operation of an independent proof-of-concept seed regeneration system.

To minimize costs, it is clear that maximum use must be made of existing MHD facilities and hardware components. The two existing Government-owned MHD facilities will be used for the POC tests. The 50 MWt scale Component Development and Integration Facility (CDIF) will be used for the integrated topping cycle tests. And, the 28 MWt scale Coal Fired Flow Facility (CFFF) will be used for the integrated bottoming cycle tests. The site for the seed regeneration POC tests has not yet been selected.

The current consensus is that it would be most appropriate to utilize an MHD steam connection concept for the retrofit in order to reduce the risks inherent in gas-side connection concepts. Other concepts will continue to be evaluated. The details of system integration depend on the relative size of the steam plant and the MHD topping cycle. The optimal method of integrating the topping and bottoming cycles will depend on the specific steam plant design.

Program Management

The MHD program management responsibility is assigned to the Director, Office of Advanced Energy Conversion Systems. The program management responsibilities include:

- Preparation of program plan
- Formulation of programmatic justification and overall program budget
- Monitoring and evaluation of program implementation progress

The MHD program implementation responsibility is assigned to the Director, Pittsburgh Energy Technology Center (PETC). The program implementation responsibilities include:

- Preparation of program implementation plan
- Preparation and maintenance of development specifications
- Implementation and monitoring of contracted effort
- Reporting technical progress and costs
- Providing budget requirements to the program manager.

PETC oversees operations at the two aforementioned Government owned, contractor operated facilities; the CDIF and the CFFF. Cost-sharing by the private sector will be implemented through appropriate contractual vehicles which will be administered by the Pittsburgh Energy Technology Center. The immediate focus of procurement activities will be (1) the competitive selection of an integration contractor with the capability, interest, business base, and corporate commitment to pursue commercialization of the MHD technology if small scale testing and operation proves successful, (2) the competitive procurement of an MHD retrofit conceptual design, and (3) the redirection of on-going activities as necessary to achieve the POC objectives described earlier. Private sector fund sharing will be required throughout the MHD POC program.

Senate Sub. on Energy
and Research Development
Asked by Sen. Domenici
Hearing of April 9, 1984

Question 2: In view of the recent series of topping cycle MHD tests performed at the CDIF and AVCO-Everett Research Labs, which have generated AC and DC electricity, would the Department summarize the total number of operating hours and power output at each facility which produced power using actual coal as the input fuel?

Answer: MHD topping cycle tests combining a TRW coal-fired combustor and an AVCO channel were conducted at AVCO's facility in Everett, Massachusetts, during the period May 17, 1982 to August 17, 1982. A total of 13 tests were conducted for operating periods totaling 24 hours. The maximum power generated during these tests was 250 KW and the nominal steady state power was 200 KW. At the CDIF, no coal-fired power generation tests have yet been conducted. The first stage of a 50 MW thermal coal-fired combustor has been installed and successfully fired and coal-fired power generation tests are scheduled for April 1985.

Question 3: The Department is proposing to undertake, with cost sharing by private industry, a conceptual design of an 80 MW thermal MHD plant, equivalent to 20 megawatts electrical output. S.1278 is proposing an MHD plant with a topping cycle component of "no less than fifty megawatts of electrical power" which, combined with the output of the bottoming-cycle steam generator, would yield a total electric output of 120 megawatts. Would the Department explain the scaling difficulties in going up in electrical output beyond the 1.5 megawatts achieved in recent tests, and why the Department has selected a 20 megawatt electric output as its base design for the phase 2 effort?

Answer: As indicated in response to question 1 above, the Department is proposing integrated testing at the scale of the CDIF and CFFF. Successful long-duration testing at this scale is necessary to bring the MHD components to the level of maturity necessary to freeze the design for the purpose of building a large fully integrated system. The Department believes that this approach represents the most timely and least costly option for proceeding to the next logical step, viz., a 5-6 fold scaleup to an MHD retrofit. While S.1278 focuses on the same end objective, viz., scaleup to a retrofit MHD facility, we believe that it adds unnecessary cost and considerable technical risk in bypassing essential long-duration proof-of-concept testing at the CDIF and CFFF.

Question 4: How much do you believe it will cost the Department to proceed with the 20 MWE (80 MWt) plant demonstration that you envision and alternately, what would be the cost of proceeding with the 50 MWe (150 MWt) topping cycle retrofit that would be called for in Senator Melcher's bill?

Answer: The estimated cost of the Department's proposed MHD program, through the proof-of-concept activities and conceptual design of an MHD retrofit, is approximately $150 million. DOE estimates of a 50 MW(e) option is about $550 million, including $250 million for R&D and $300 million for the retrofit plant.

Senate Sub. on Energy
and Research Development
Asked by Sen. Domenici
Hearing of April 9, 1984

Question 5: In view of the large Soviet MHD program which is presently constructing a 500 megawatt (electric) power plant and has decided to make exclusive use of natural gas despite its large coal reserves, estimated to be 3/4 of our reserves, does the Department believe that the Soviet technology has uncovered any major technical or reliability problems with coal-fired MHD?

Answer: It is our understanding that the Soviet program of MHD research and development provides for a phased commercialization of MHD power plants starting with gas-fired plants, to be followed, after adequate research and the accumulation of operating experience, by coal-fired plants. Gas-fired MHD is technically much easier to develop than coal-fired MHD. That consideration, and the plentiful supply of natural gas in the Soviet Union, are probable motives for their starting with gas-fired units. While we know that some efforts have been undertaken on coal-fired MHD plants, we are not aware of the status of such efforts.

Question 6: In the Department's technical surveying experience, is there any evidence in foreign countries of successful operation of coal-fired MHD plants at an electric power of one megawatt or above or is this particular technology demonstration exclusive to the DOE programs at present?

Answer: To our knowledge there are no coal-fired MHD plants of any size in operation in foreign countries.

Question 7: Would the Department provide for the record, the section on Magnetohydrodynamics in the report "Federal Energy R&D Priorities" as issued by the Energy Research Advisory Board to the Department in November 1981.

Answer: Enclosed is a copy of the title page and copies of the statements on MHD contained in the "Federal Energy R&D Priorities" report issued by the Energy Research Advisory Board in November 1981.

Federal Energy R&D Priorities

Report of the
Energy Research Advisory Board

November 1981

U.S. Department of Energy

D. Non-nuclear Electric Programs*

Solar power technology ($112.1/$19.4) This technology area includes wind energy and Ocean Thermal Energy Conversion (Photovoltaics is included under Solar Applications for Building in the conservation section.) Wind energy is regarded as the most technologically advanced and as having achieved commercial potential. Since there are no critical technical R&D problems preventing commercialization by industry, and since there is limited potential to be realized, the Board recommends less funding for this technology. In the case of OTEC, technical feasibility has been shown on a small scale, thus fulfilling the primary Federal role. The Board recommends that remaining funding should be used to faciliate the transition to industrial commercialization.

Hydropower ($2.4/$0.0) Technical success for small scale hydropower has been proved, and private industry is active (although it is noted that U.S. manufacturers of low-head hydro equipment are absent). Little, if any, R&D is needed; therefore, the Board recommends phase-out of funding. Investment tax and other credits are sufficient to commercialize this technology.

Magnetohydrodynamics ($66.5/$0.0) There are other technologies (such as combined cycle gas turbines) available for increasing the efficiency of large, central power generation stations that do not have the extreme temperature/erosion problems associated with the use of coal in MHD. For this reason the Board foresees little commercial demand for this technology and therefore concurs with the planned phase-out of this program. The Board recommends that existing government facilities be utilized by industry if they wish to pursue research in this area.

Geothermal ($153.6/$46.8) Strong agreement that funding should be decreased is predicated upon the fact that private industry should be undertaking the development of the part of the resource that appears economic, and is in fact doing so. The program is also seen as having low impact on national energy supply. If a Federal geothermal program is continued, emphasis should be on low temperature process heat and completing the ongoing hot dry rock program, not on geopressured energy resources, where the technical risk appears high or geothermal electric where industry is capable of solving the remaining problems.

Electric Energy and Storage ($109.8/$47.5) This program consists of two parts, R&D on electricity transmission and distribution and R&D on energy storage. R&D on electricity transmission and distribution is regarded as essentially the responsibility of private industry. As a result, there is agreement that the overall program should decrease in such a way that at least some results can be obtained from programs now at the point of yielding valuable data. R&D on energy storage, however, is regarded as important; this part of the program should be strengthened. The Board supports direct participation of Federal electricity producing and marketing agencies in the Electric Power Research Institute as a mechanism for supporting R&D on utility-related needs.

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*Dispersed electric and co-generation technology, direct coal combustion, and fuel cell programs included in Section VI.

TABLE VIII-A

RELATIVE PROGRAM RANKING[1]

	Electric		Fuel Supply		Conservation & Utilization		Science & Technology Base[4]	
Priority[2]	Programs	Funding[3]	Programs	Funding[3]	Programs	Funding[3]	Programs	Funding[3]
HIGHER							Materials Sciences	More
							Climate & CO_2 Research	More
							Chemical Sciences	More
	Commercial Nuclear Waste	Same					Biol/Environmental Research	More
							Biological Energy Sciences	More
					Coal Combustion	Same	Nuclear Medicine	Same
	Defense Nuclear Waste	Same			Buildings/Community Systems	More	High Energy Physics	Same
					Industrial Conservation	More	University Research	More
			Enhanced Oil Recovery	Less				
							Environment & Safety	Same
							Engineering/Math/Geosciences	Same
							Nuclear Physics	Same
MEDIUM	Conventional Reactors	More	Advanced Technology	Same	Transportation Conservation	Same		
			Enhanced Gas Recovery	Less	Solar Applications/Bldgs	Same		
	Breeder Fuel Cycle R&D	Little Less					Nuclear Sciences	Same
	Centrifuge	Same						
	LMFBR	Same			Heat Engines/Heat Recovery	Same		
			Coal Liquefaction	Less			Advanced Energy Projects	Same
	Solar Power Technology	Less			Multi-Sectors Conservation	Same		
	Advanced Isotope Separation	Same			Fuel Cells	Same		
			Biomass Energy	Same				
			Surface Coal Gasification	Less				
LOWER			Mining R&D	Less	Solar Applications/Industry	Less		
	Magnetic Fusion	Little Less	In-Situ Oil Shale	Less			Technology Assessments	Same
	Light Water Breeder	Less						
	Uranium Resource	Same						
	Electric Energy/Storage	Less						
	Hydropower	Zero						
	Clinch River Breeder	Less						
	Geothermal	Less						
			Alcohol Fuels	Same				
			In-Situ Coal Gasification	Less				
	Magnetohydrodynamics	Zero						

[1] Rankings represent consensus view of ERAB and should be interpreted with caution; the differentiation between any two consecutive programs is not necessarily significant.

[2] Priority reflects ERAB view of overall merit of program; funding recommendations relative to the President's FY82 request of March 1981.

[3] Budget numbers refer to President's FY82 request of March 1981 (excluding program direction).

[4] Science and technology base programs were evaluated by a different set of criteria from the R&D programs and are not directly comparable to them.

3. With respect to fusion, ERAB members agree on the long-term importance of this program and that the primary Federal role should be to continue to sponsor a joint program of the Federal laboratories, industry and university scientific communities to determine if fusion can be practical. The potential payoff is very large, but is much too far in the future for significant private sector support. There was agreement that a stretch-out of the program is possible if budgetary pressures demanded it, but maintenance of a substantial level of Federal R&D funding is judged to be essential. It is also recommended that an enhanced effort to examine the use of fusion for the breeding of nuclear fuels deserves consideration.

4. Finally, there are several electric programs for which funding should be reduced or eliminated (such as solar power technology, light water breeder reactors, electric transmission systems, geothermal, magnetohydrodynamics, and hydropower) due to their relatively small contribution to electric supplies in comparison with other programs.

C. Liquid and Gas Supply R&D Programs

With regard to Liquid and Gas Supply R&D Programs, the major conclusions of the Board are as follows:

1. With respect to enhanced oil and gas R&D recovery programs, the ERAB concluded that the U.S. oil and gas industry has sufficient resources and financial incentives to develop these technologies without substantial government assistance. The Board concluded that, even though these programs are important from the standpoint of urgency and energy security, the Federal R&D role should be minimal with less Federal funding needed.

2. With regard to coal liquefaction and coal gasification, it was concluded that large-scale demonstration projects involving substantial cost-shared Federal outlays are not necessary or appropriate considering the financial guarantees (e.g., loan guarantees, price guarantees) that are available from DOE and the Synthetic Fuels Corporation. The major Federal effort in synthetic fuels research and development should be directed at innovative concepts in the laboratory and small pilot-plant scale with particular emphasis toward exploring a wider range of technological options with potential for significant efficiency and cost improvements. The Board recommends a reduced budget for DOE's cost-shared projects at the large pilot plant and demonstration-plant scale.

3. With respect to in-situ oil shale recovery, the Board recommends a decrease in funding based on the fact that several major oil companies have in-situ shale projects that do not involve Federal assistance.

4. The funding level for R&D directed at producing liquids and gases from biomass and the production of alcohol is at an appropriate level.*

5. Continuing increases in the price of conventional oil and gas suggest that the time when coal and oil shale will be economic sources of oil may be near. This situation is stimulating the private sector to consider some commercial operations by 1990. ERAB concludes that the private sector can be expected to carry out important actions that justify a lessening of DOE research in these technologies. However, it is recommended that DOE accelerate its research in environmental problems and infrastructure problems associated with the commercialization of these technologies.

6. The bulk of the coal produced for the next several decades will be used directly as boiler fuel, both in existing and new units, reducing dependence on oil and gas for this purpose. But improved emission control technologies to reduce SO_x, NO_x and particulate emission in flue gases will be essential to the success of this effort. ERAB therefore urges that this part of the Advanced Research and Environmental Control Technology (FE) programs be increased and given higher priority at the expense of the other activities in this program.

D. Conservation and Utilization R&D Programs

With regard to Conservation and Utilization R&D Programs, the major conclusions of the Board are as follows:

1. The overall level of Federal R&D funding for conservation and improved utilization programs is too low in view of their potential for energy improvements and the inability of many important energy-consuming sectors to conduct R&D. Moreover, Department-wide, the balance between supply oriented R&D and conservation R&D is too heavily weighted toward the supply side.

2. The Board concluded that R&D in Buildings and Community Systems needs increased funding in view of the large amount of energy consumed in this sector and the lack of private sector institutions able to undertake building systems R&D. This is particularly true in the case of the important retrofit technologies.

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*See ERAB reports on Biomass and Alcohol Fuels.

TABLE B-1
ENERGY RD&D PROGRAM BUDGET SUMMARY

	Congressional Budget Authority FY 81*	President's Request (March) FY 82	ERAB Recommendation[1]	Congressional Appropriation FY 82
	(in $thousands)			
A. Electric-Related Supply				
1. Magnetohydrodynamics (FE)	$ 66,533	$ 0	ZERO	$ 29,000
2. Geothermal (CE)	153,645	46,775	LESS	61,266
3. Hydropower (CE)	2,409	0	ZERO	2,750
4. Electrical Energy Systems and Energy Storage Systems (CE)	109,800	47,525	LESS	65,125
5. Solar Power Technology (CE)	112,100	19,400	LESS	56,200
6. Magnetic Fusion (ER)	391,000	456,100	LITTLE LESS	452,100
7. Uranium Resource Assessment (NE)	25,925	5,800	SAME	5,800
8. Uranium Enrichment (NE)				
a-Centrifuge (NE)	356,315	759,800	SAME	691,358
b-Advanced Isotope Separation (NE)	79,300	85,237	SAME	85,237
9. Conventional Reactor Systems (NE)	81,500	68,000	MORE	115,250
10. Breeder Reactors (NE)				
a-Liquid Metal Fast Breeder	371,919	387,842	SAME	403,342
b-Clinch River Breeder	172,000	254,000	LESS	195,000
c-Light Water Breeder	60,200	58,000	LESS	52,000
d-Fuel Cycle R&D	47,500	26,100	LITTLE LESS	26,100
11. Nuclear Waste				
a-Commercial (NE)	201,415	227,551	SAME	207,400
b-Defense (DP)	298,445	390,000	SAME	371,731
12. Mining R&D (FE)	40,169	21,000	LESS	13,950
Subtotal	2,570,175	2,853,130		2,833,609
B. Liquids and Gas-Related Supply				
13. Advanced Technology (FE)	57,833	94,500	SAME	58,100
14. Coal liquefaction (FE)	276,997	105,200	LESS	237,200
15. Surface Coal Gasification (FE)	69,618	53,440	LESS	54,750
16. In-Situ Coal Gasification (FE)	9,960	8,300	LESS	8,300
17. Enhanced Oil Recovery (FE)	16,518	20,100	LESS	16,100
18. Enhanced Gas Recovery (FE)	30,598	10,200	LESS	12,200
19. In-Situ Oil Shale (FE)	32,151	16,250	LESS	18,950
20. Biomass Energy (CE)	31,650	20,500	SAME	30,500
21. Alcohol Fuels (CE)	18,000	10,000	SAME	0
Subtotal	543,015	338,490		436,100

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*Includes deferrals. Excludes recissions and program direction.

[1] ERAB recommendations for FY 83 budget, compared to President's FY 82 request of March 1981.

Senate Sub. on Energy
and Research Development
Asked by Sen. Bradley
Hearing of April 9, 1984

Question 1: Can you describe briefly the advantages of pressurized fluidized bed combustion technology, when compared to standard coal burning?

Answer: Advantages of PFB technology over conventional coal-fired utility plants with flue gas desulfurization include higher efficiency with the potential to decrease capital and operation costs thereby reducing the cost of electricity; the ability of a single combustor/boiler to use different types of coals, with widely varying heat content and sulfur content; superior environmental performance; and modularity with no great cost penalty for loss of economics of scale. Modularity would enable a utility to install a PFB in incremental steps permitting operation with a smaller capacity margin, thereby reducing overall costs.

Question 2: Does pressurized fluidized bed technology have potential to help treat the acid rain problem?

Answer: Pressurized fluidized bed (PFB) technology does have the potential to help treat the acid rain problem because of its ability to remove in excess of 95 percent of the sulfur in coal during combustion and because of its inherently low NO_x emissions. These are believed to be precursors to acid rain. PFB also has potential as a retrofit technology for existing coal-fired power plants thereby reducing current SO_2 and NO_x emissions while increasing the electricity output and efficiency above that of the existing facility. However, it not clear that PFB will be economically competitive with other acid-rain control measures. It will be more capital intensive than conventional alternatives, but it may have lower operating costs.

Question 3: How much money has DOE spent on this technology over the past five years?

Answer: Over the past five years, DOE has spent approximately $70.0 million on PFB technology.

Question 4: Could you describe the status of the 13 megawatt pilot plant in Woodridge, New Jersey?

Answer: The construction of the 13 megawatt pilot plant was completed November 30, 1983, when the facility components pressure vessels and process piping were installed and erected. However, no subsystem operational checkouts have been attempted. Discussions are under way to close out the cooperative agreement with Curtiss-Wright.

Question 5: Has the plant ever operated?

Answer: The 13 megawatt pilot plant has never operated.

Senate Sub. on Energy
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Asked by Sen. Bradley
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Question 6: Is private industry willing to put up more money so to operate the plant? (Yes. Public Service Electric and Gas, Burns and Roe, and others.)

Answer: An unsolicited proposal was received from an industrial team consisting of Public Service Electric and Gas Research Corporation (PSE&G) and Burns and Roe who proposed to cost share in the amount of $3,500,000. The Empire State Electric Energy Research Corporation proposed to contribute an additional $1,000,000 contingent on formal approval by the board and test burning of Pittsburgh #8 coal. It is noted that an estimated additional amount in excess of $21.0 million would be required from either Federal funds or unidentified private sector sources over the cost sharing identified above to operate the plant over a two year period.

PSE&G has been advised that DOE has no funds for the operation of the pilot plant and sees no programmatic need for it since it is an air cycle plant whereas the steam cycle is considered the favored technology for PFB commercial development.

Question 7: Will this plant ever run?

Answer: It is unlikely that the plant will ever start operation. No funds to operate the plant are included in the FY 1985 budget.

Senate Sub. on Energy
and Research Development
Asked by Sen. Ford
Hearing of April 9, 1984

DOE - Industry Agreement on R&D Priorities

Question: I understand that the Department has been meeting with representatives of the private sector with an interest in MHD to reach agreement on the structure of the MHD research and development program. Please provide the Committee with a status report on these meetings. Based on the state of your negotiations so far, do you expect to modify your budget request for the MHD program?

Answer: The Department initiated a series of public meetings in February 1984 pursuant to the proposed redirection of the MHD program. There was substantial agreement reached as a result of these meetings regarding the status of MHD development and the additional work that needs to be done. As a result of inputs received at the public meetings and DOE analyses, the Department transmitted a proposal to Congress for the redirection of the MHD program. A copy of that transmittal, dated June 6, 1984, is enclosed. Subsequent public meetings, focused on cost sharing, have been encouraging.

The DOE Congressional budget request for MHD was $17.8 million. When the MHD preliminary transition and program plan was transmitted to Congress in June 1984, an FY 1985 funding level of $29.8 million was needed to implement the revised MHD program. The Department of the Interior and Related Agencies Appropriations Act, 1985, (Pub.L. No. 98-473) provides $31.5 million for the MHD program.

COAL FIRED MHD SYSTEMS

PRELIMINARY TRANSITION AND PROGRAM PLAN

Overview

The Department of Energy (DOE) has in close consultation with the private sector, undertaken to realign the national MHD program. This paper outlines DOE's views on how the national program should proceed. The historic program which focused on subsystems development will be redirected to a multiyear program targeted on the achievement of proof-of-concept (POC) testing. Following the successful completion of the POC tests, the next logical MHD development step would be a fully integrated, coal fired, MHD retrofit.

The key components of the new program include:

- The design, construction, and operation of: (1) an integrated topping cycle, (i.e., an MHD power train), (2) an integrated bottoming cycle (i.e., a heat recovery/seed recovery subsystem) and (3) a seed regeneration system. These systems/subsystems will provide proof-of-concepts which are critical to the advancement of the technology to the MHD retrofit stage.
- Baseline subsystems development efforts to acquire the knowledge necessary to proceed with the integrated test facilities and the seed regeneration system.

The POC activities will proceed on concurrent, interrelated paths in a plan that will make optimum use of existing components and facilities.

The proposed program includes a flexible, cost-sharing arrangement designed to elicit a commitment from the private sector in the integrated systems and subsystems. Discussions with industry pertaining to cost-sharing were initiated in early February 1984. Preliminary indications suggest that the private sector may be willing to offer some cost sharing. The amount of cost-sharing will influence the pace of the program.

Assuming that there is adequate cost-sharing and subject to the availability of Congressionally appropriated funds, the new program will be initiated in FY 1985.

A conceptual design of the MHD retrofit system will be started in FY 1985 concurrently with the POC activities. The long duration POC testing of the topping and bottoming cycles will commence in FY 1987. Bench scale seed regeneration work will be initiated in FY 1985, leading to the design, construction and operation of a POC seed regeneration system by the late 1980s.

If the topping and bottoming cycle POC tests described earlier are successful, the next logical step would be the preliminary design (Title I) of the MHD retrofit in FY 1987 and with the detailed design (Title II) in late FY 1987 or early FY 1989. It is expected that at this stage the program would become largely a private sector responsibility with DOE's role limited to providing technical advise and possibly some funding support, depending upon its R&D benefits. In any event, it is premature to make any commitment technically to proceeding with the detailed design and construction of a retrofit project pending results of the POC. These results are not expected until 1987 or 1988.

The total program cost through the POC and conceptual design of an MHD retrofit, including private sector cost-sharing, is estimated to be approximately $150 million. The cost of the MHD retrofit will depend on the final design, configuration and site specific factors associated with the retrofit.

The FY 1984 program is directed towards the acquisition of data on the performance and operation of major subsystems. These activities will contribute significantly to the success of the integrated POC activities. Accordingly, the available FY 1984 funds will be focused to ensure the early completion of key activities.

Background

MHD is the highest temperature heat engine under development within Fossil Energy, hence it has the highest theoretical systems efficiency of any heat engine. However, it is the least mature technically and has the highest cost and longest lead time for ultimate development. The operating principle involves the direct combustion of coal to yield an electrically conductive gas which is then directly converted to electrical power when passed through a magnetic field. Afterwards, the high temperature gas is driven through a boiler to raise steam and generate additional electric power. The high performance (efficiency) potential of MHD power systems could permit its future utilization in electric utility systems. The high temperatures of the MHD combustor also provides the potential for the direct burning of any coal, regardless of its heating value and contaminant content. Environmentally, MHD also offers the advantage that most of the sulfur contained in the coal is removed by the MHD process.

The MHD program has reached a critical decision point; the technology is ready for integrated proof-of-concept system/subsystem tests. It is now time to focus the program on the least-cost, shortest development time path to establish the technology base for MHD power systems so that the private sector can subsequently commercialize the technology.

The technical status of MHD technology has recently been evaluated by Westinghouse, General Electric, Gilbert Associates, Inc., and the Argonne National Laboratory. Their conclusions as to the present technical status of key MHD components and what is required to bring them to a state of technical readiness sufficient for subsequent private sector commercialization include the following:

- The coal preparation and feeding subsystem does not represent a major technical issue. Nevertheless, scaleup, integration with MHD systems, electrical isolation and durability must be demonstrated.
- In the seed subsystem, preparation and feeding are not major technical issues but integration with MHD systems and durability must be demonstrated.
- The oxygen plant is considered commercially available and is not a major technical issue.
- Coal combustor development is considered a key technical issue in that scaleup, performance, and durability all remain to be demonstrated.
- Nozzle development is not a major technical issue. It is considered within the current state-of-the-art but must be integrated with MHD.
- Channel development is considered a key technical issue. Scaleup, long-term performance, and durability, all remain to be demonstrated.

- Diffuser development is not considered a major technical issue. Scaleup and integration with MHD must be demonstrated, however, particularly with regard to channel replacement.

- Inverter development is a moderate technical issue in that the current consolidation and control networks must still be developed and demonstrated.

- Superconducting magnet development is not considered a major technical issue but field constructability and integration with an MHD channel remain to be demonstrated.

- Emission control for MHD is not considered a major technical issue. However, scaleup and demonstration under actual MHD integrated system conditions remain to be undertaken.

- Development of the waste heat boiler, superheater, and low temperature oxidant preheater is considered a key technical issue. No large-scale testing or integration with MHD has yet been undertaken.

- Seed recovery and regeneration are considered key technical issues. Seed recovery has not yet been demonstrated in an integrated system and no process development has been undertaken.

- A high temperature air heater is not required for the early-commercial MHD powerplant concept.

- Economizer and low temperature air heater development are not major technical issues for MHD. These subsystems are already in use in full size powerplants.

While a number of technical issues remain, as described above, the primary uncertainties are:

- Downstream chemistry (seed recovery, seed regeneration, and related issues).

- Large-scale, long-duration, coal-fired, integrated system operation.

- Long duration coal combustor performance and scaling effects. Also more work is needed on channel durability and performance at high interaction levels.

It is estimated that it will take approximately 3 years to develop the necessary design information for the key MHD components for the MHD retrofit. Development of the seed regeneration subsystem data will probably require an additional year or two, i.e., 3-5 years.

DOE has developed a proposed program to serve as the basis of discussions with the Congress and the private-sector pursuant to redirecting the MHD program. The elements of the proposal and a preliminary transition plan are discussed in the remainder of this document.

Preliminary Transition Plan

The FY 1985 funding will be targeted on bringing the individual components and subsystems to comparable levels of technical maturity. Contractors' activities will primarily focus upon hardware development and testing to produce hardware for long duration testing at the integrated facilities. Hardware and subsystem tests will be continuations of efforts in progress under the FY 1984 program and will make maximum use of existing contractors' hardware and facilities.

It should be recognized that a detailed transition plan cannot be produced at this time because of the preliminary nature of the present program plan. The final program development, planning and implementation must take into consideration that the program will be a cost-shared venture in which the paying parties will expect to exercise a voice proportionate to their contributions. The final program will also be influenced by negotiations on cost-sharing and other program aspects.

Proposed Approach

The POC test facilities comprise two integrated subsystems, an MHD topping cycle and a steam bottoming cycle. The overall topping cycle layout is prototypical of early commercial plant design in that intermediate-temperature (1200 F), oxygen enriched air would be used as the oxidizer (fully developed and more efficient MHD plants are expected to employ high temperature (2900 F) air as the oxidizer).

As presently contemplated, the MHD topping cycle would be operated with the combustor at approximately 6 atmospheres and electrically isolated. The topping cycle would be capable of being operated continuously for extended periods (100 to 1000 hours) between shutdown. The MHD generator would be operated supersonically utilizing a superconducting magnet capable of continuous operation at a magnetic field strength up to 4.5 Tesla and all power conditioning electronics necessary to optimally interface the channel with the inverter components.

The heat recovery and seed recovery (HRSR) subsystem would incorporate critical elements necessary for the simulation of the MHD steam bottoming cycle. Specifically, the HRSR would include the hardware necessary for steam raising, seed, ash and slag collection, seed recovery from slag/ash mixtures, environmental effluent control, and ancillary components.

Work on the development of seed regeneration subsystems has lagged that of other MHD developmental efforts. As a result, it would not likely be possible to specify the regeneration process requirements in a time-scale compatible with their integration into the detailed HRSR system design. Therefore, the seed regeneration subsystem will be considered independent of the HRSR subsystem; this approach will lead to more flexible operation of the seed regeneration system and will not result in the loss of vital process data. Present preliminary plans include the conduct of bench scale tests followed by the design, construction, and operation of an independent proof-of-concept seed regeneration system.

To minimize costs, it is clear that maximum use must be made of existing MHD facilities and hardware components. The two existing Government-owned MHD facilities will be used for the POC tests. The 50 MWt scale Component Development and Integration Facility (CDIF) will be used for the integrated topping cycle tests. And, the 28 MWt scale Coal Fired Flow Facility (CFFF) will be used for the integrated bottoming cycle tests. The site for the seed regeneration POC tests has not yet been selected.

The current consensus is that it would be most appropriate to utilize an MHD steam connection concept for the retrofit in order to reduce the risks inherent in gas-side connection concepts. Other concepts will continue to be evaluated. The details of system integration depend on the relative size of the steam plant and the MHD topping cycle. The optimal method of integrating the topping and bottoming cycles will depend on the specific steam plant design.

Program Management

The MHD program management responsibility is assigned to the Director, Office of Advanced Energy Conversion Systems. The program management responsibilities include:

- Preparation of program plan
- Formulation of programmatic justification and overall program budget
- Monitoring and evaluation of program implementation progress

The MHD program implementation responsibility is assigned to the Director, Pittsburgh Energy Technology Center (PETC). The program implementation responsibilities include:

- Preparation of program implementation plan
- Preparation and maintenance of development specifications
- Implementation and monitoring of contracted effort
- Reporting technical progress and costs
- Providing budget requirements to the program manager.

PETC oversees operations at the two aforementioned Government owned, contractor operated facilities; the CDIF and the CFFF. Cost-sharing by the private sector will be implemented through appropriate contractual vehicles which will be administered by the Pittsburgh Energy Technology Center. The immediate focus of procurement activities will be (1) the competitive selection of an integration contractor with the capability, interest, business base, and corporate commitment to pursue commercialization of the MHD technology if small scale testing and operation proves successful, (2) the competitive procurement of an MHD retrofit conceptual design, and (3) the redirection of on-going activities as necessary to achieve the POC objectives described earlier. Private sector fund sharing will be required throughout the MHD POC program.

Senate Sub. on Energy
and Research Development
Asked by Sen. Ford
Hearing of April 9, 1984

Patents

Question: Please describe the policy towards patents that the Department uses in connection with MHD development. Do you believe that this policy provides adequate incentives for investing in government-sponsored technology?

Answer: The Department of Energy policies on patents are based upon 35 USC 202 as recently amended, 42 USC 2182 and 42 USC 5908. Under 35 USC 202, small business and nonprofit contractors, except for certain exemptions, may elect to retain title to inventions arising under their contract work. The other statutes provide that the title be retained by the government for patents developed by businesses under government contract. Under these statutes large businesses may request waivers either at the time of the contract negotiations or on a case-by-case basis. Waivers are granted by the Department if they are determined to be in the public interest. Such determination is based on the objectives and considerations for waivers as set forth in the DOE patent regulations including the Presidential Memorandum on Patent Policy of 1983. Waiver determinations are subject to the concurrence of the program office responsible for the MHD program.

We believe that these policies provide adequate incentives for industry participation in the MHD program.

Cost-Sharing

Question: S.1278 calls for a contribution by the private sector of at least 40 percent of the cost of the MHD demonstration project authorized by section 5 of S.1278. How would the Administration interpret this requirement? Would in-kind contributions qualify? Why or why not?

Answer: S.1278 specifies that no more than 60 percent of the funding be borne by the government. DOE estimates place the cost of such a program at about $550 million ($250 million for R&D and $300 million for the demonstration plant). Accordingly, the cost to the government would be approximately $330 million. In-kind contributions would have to be evaluated on an individual basis.

Senate Sub. on Energy
and Research Development
Asked by Sen. Ford
Hearing of April 9, 1984

S.1278

Question: Please give us the Administration's views on S.1278. How does the program you have proposed for MHD development in your FY 1985 budget request differ from the provisions of S.1278? How is your program similar to the program outlined in S.1278?

Answer: The principal differences between the development efforts proposed by DOE's FY 1985 budget request and S.1278 are:

> S.1278 specifies a facility of no less than 50 MW electrical from the MHD portion of the process (the "topping cycle") while the DOE "proof-of-concept" (POC) facilities would be sized at approximately 50 MW(e) to the MHD topping cycle and about 28 MW(t) to the bottoming cycle.
>
> S.1278 specifies operation of a utility retrofit facility by 1992. The timing of a retrofit project under the current DOE program would be determined by the success of the POC and the willingness of industry to bear the major costs of the facility;
>
> S.1278 specifies that no more than 60 percent of the funding be borne by the Federal government. The DOE program is based on a flexible cost-sharing arrangement through proof-of-concept. If the POC tests are successful, the Department anticipates that commercial-scale demonstration would become largely a private sector responsibility, with DOE's role limited to providing advice and possibly some funding for supporting R&D, depending on the overall benefits of such works.
>
> S.1278 is specific in regard to retrofitting an existing electric powerplant. The DOE program would conduct POC tests, utilizing existing test facilities, prior to the utility retrofit. Both approaches would transmit coal-fired MHD-generated power to a utility grid;
>
> S.1278 requires the establishment of a Technical Review Panel. The DOE program does not propose to address the details of program management for the utility retrofit until an indication of industrial involvement can be obtained.

As in any development effort, a judgment must be made as to the proper pace of large-scale development efforts compared to proof-of-concept testing. The Department believes it has recommended a program which incorporates a prudent mix of effort. With few exceptions, even the most mature MHD components and subsystems require extensive efforts to reduce the risk of an unsuccessful and unnecessarily costly expenditure of funds for an integrated MHD test system.

While S.1278 focuses on an appropriate end objective, viz., scaleup to a large retrofit MHD facility by industry, we believe it adds unnecessary cost and considerable technical risk in bypassing an intermediate integrated system test in order to demonstrate the technology at a larger scale within a mandated period of time.

Senate Sub. on Energy
and Research Development
Asked by Sen. Ford
Hearing of April 9, 1984

Amendments

Question: Wouldn't it be helpful to enact a definite program for MHD development with stable funding, agreed-upon goals and milestones, and an objective oversight mechanism? Please provide the Committee with a list of amendments desired by the Administration in order to obtain your support for the legislation.

Answer: The Department estimates that a FY 1985 funding level of $29.8 million is sufficient to initiate a multiyear program targeted on the achievement of proof-of-concept testing. An estimate, by fiscal year, of budget and outyear allocations through the fiscal year 1990 indicates expenditures of about $30 million per year with significant cost-sharing by industry. We do not foresee the need for special legislation to achieve the goals set for the MHD program.

S.1925

Question: If S.1925 were enacted and fully appropriated as an addition to the current level of fossil R&D program activity, the total appropriation would still be less than that appropriated in either FY 1981 or FY 1982, would it not? It would still be less than your budget request for FY 1985 for fusion or for fission research and development, would it not?

Answer: The Fossil Energy appropriation for FY 1981 (P.L. 96-514) was $1,134.7 million and for FY 1982 (P.L. 97-100) was $416.9 million. The FY 1985 DOE request for Magnetic Fusion and Nuclear Energy R&D was $483.1 million and $618.1 million, respectively.

If S.1925 were enacted and fully appropriated, a total of $775 million would be added to the FY 1985 Fossil Energy appropriated amount of $274.9 million included in the recently passed Conference report for a total of $1,049.9 million. This amount is greater than the Department's request for Magnetic Fusion or Nuclear Energy R&D for FY 1985, greater than the funds appropriated for Fossil Energy in FY 1982, and less than the funds appropriated for Fossil Energy in FY 1981.

Senate Committee on
Energy and Natural
Resources (Johnston)
May 1, 1984

MHD

Question 1: I understand that the Department has been meeting with representatives of the private sector with an interest in MHD to reach agreement on the structure of the MHD research and development program. Please provide the Committee with a status report on these meetings. Based on the state of your negotiations so far, do you expect to modify your budget request for the MHD program?

Answer: Discussions with the private sector pertaining to the redirection of the MHD program were initiated in early February 1984. DOE and industry have presented alternative proposals which are being examined in more detail. A government/industry consensus on the status of MHD technology has emerged. Additional meetings have been scheduled to further discuss alternative proposals, technical risk and cost-sharing. Overall, government/industry discussions have been constructive. Since these discussions are continuing, we believe that any modifications of the Department's FY 1985 budget request would be premature.

Senate Committee on
Energy and Natural
Resources (Johnston)
May 1, 1984

MHD

Question 2: Please describe the policy towards patents that the Department uses in connection with MHD development. Do you believe that this policy provides adequate incentives for investing in government-sponsored technology?

Answer: The Department of Energy policies on patents are based upon 42 USC 2182 and 42 USC 5908. Generally, large businesses may request waivers either at the time of the contract negotiations or on a case-by-case basis. Waivers are granted by the Department if they are determined to be in the public interest. Such determination is based on the objectives and considerations for waivers as set forth in the DOE patent regulations including the Presidential Memorandum of Patent Policy of 1983 to the extent not inconsistent with the statute. Waiver determinations are subject to the concurrence of the program office responsible for the MHD program. Historically, the MHD program managers have favored the retention of patent rights in appropriate cases.

Small businesses, universities and non-profit institutions are covered by P.L. 96-517 which provides them with automatic retention of the patent rights. They need no waivers.

MHD

Question 3: S.1278 calls for a contribution by the private sector of at least 40 percent of the cost of the MHD demonstration project authorized by section 5 of S.1278. How would the Administration interpret this requirement? Would in-kind contributions qualify? Why or why not?

Answer: Our interpretation of the S.1278 cost-sharing proposal is that the Federal government would assume no more than 60 percent of the facility costs.

In-kind contributions will be considered, provided such contributions do not originate from Federal funding such as government owned or supplied facilities.

Senate Committee on
Energy and Natural
Resources (Johnston)
May 1, 1984

MHD

Question 4: Please give us the Administration's view on S.1278. How does the program you have proposed for MHD development in your FY 1985 budget request differ from the provisions of S.1278? How is your program similar to the program outlined in S.1278?

Answer: While S.1278 focuses on an appropriate end objective, scale-up to a larger retrofit MHD facility by industry, we believe that it adds unnecessary cost and considerable technical risk in bypassing intermediate integrated system tests in order to demonstrate the technology at a larger scale within an arbitrarily short period of time.

We believe that the Department's proposed MHD R&D program leading to an intermediate-scale test facility is a more prudent approach and is preferable to S.1278.

The principal differences between the development efforts proposed by DOE's FY 1985 budget request and S.1278 are:

o S.1278 specifies a facility of no less than 50 MW electrical from the MHD portion of the process (the "topping cycle") while the DOE "proof-of-concept" facility would be sized at approximately 8 MW of electrical generation from the MHD topping cycle and about 20 MW electrical overall (or a total of about 80 megawatts thermal);

o S.1278 specifies operation of the facility by 1992. The schedule of the DOE proposed program would be determined, in a large measure, by the results of government-industry negotiations on the scope and timing of the program and the extent of private sector cost-sharing.

- S.1278 specifies that no more than 60 percent of the funding be borne by the federal government. The DOE program is based on a recommended level of cost-sharing by the federal government of 50 percent, with adjustments to the scope and schedule of the program to be made depending upon the level of industry support;

The similarities between S.1278 and the DOE position are presented in the attached side-by-side comparison.

MELCHER BILL (S.1278)	DOE POSITION
OBJECTIVES	**OBJECTIVES**
"To provide for an accelerated program of research, development, and demonstration with respect to the production of electricity from magnetohydrodynamics, leading to the construction and operation of at least one major proof of concept demonstration project in connection with an existing electric powerplant, and for other purposes."	The objectives of the Magnetohydrodynamics (MHD) program are to acquire the scientific data necessary to resolve key technical issues and to design, construct, and operate an integrated, coal-fired MHD combined cycle system at the approximately 80 megawatt (thermal) level that will be cost-shared with the private sector.
PERCEPTIONS **Barriers/Status**	**PERCEPTIONS** **Barriers/Status**
"...although the basic technology of magnetohydrodynamics is available, commercial acceptance of this technology is inhibited by the lack of an adequate Federal program for research, development and demonstration with respect to magnetohydrodynamics;" "...magnetohydrodynamic technology is ready for a proof of concept demonstration on a scale sufficient to provide reliability and operational data to support commercial evaluation of the technology;"	With the few exceptions, even the most mature MHD components and subsystems require extensive efforts to reduce the risk of unsuccessful design and a major effort is needed to begin to resolve critical issues associated with the continuous operation of an integrated MHD system. The ultimate success of MHD technology requires that a science base R&D program be conducted to support a multi-year effort targeted on the successful operation of an integrated test system.
SCIENTIFIC RESEARCH PHASE	**SCIENTIFIC RESEARCH PHASE**
"The Secretary shall conduct and provide support for such research and development as he determines will most expeditiously clarify the scientific and technical issues that directly affect the development and commercial acceptance of magnetohydrodynamic technology."	The FY 1985 funding request is for a two phase, multi-year program. The objectives of the program are to (1) pursue (in Phase 1) a scientific research effort to address the key technical issues in order to establish a technology base for future component development. The MHD scientific program (Phase 1) will be directed specifically towards resolving technical issues associated with coal-fired, open-cycle, combined MHD/steam electric power generation systems. Significant technical problems exist with respect to both the MHD topping and steam bottoming cycles. These problems include, for example, the electrical isolation of

major subsystems including the combustor and channel; the development of high temperature air heater designs capable of delivering combustion air at temperatures up to 3000°F; definition of the design and operating conditions required to suppress ash fouling effects in the heavily loaded bottoming cycle gas stream; and recovery and regeneration of the process K_2CO_3/K_2SO_4 seed burden. Consequently, the major thrust of the scientific program will be to obtain a systematic data base to ultimately support the future development of these subsystems. Finally, a detailed system analysis will be conducted to more precisely characterize and quantify technology issues requiring resolution and a data base that ultimately will allow development and commercialization of the technology.

MHD FACILITY	MHD FACILITY
"The Secretary shall offer to enter into an agreement in accordance with this section with the owner of an existing, coal-fired, electric powerplant, and with such other persons as the Secretary deems appropriate, for a proof of concept demonstration of magnetohydrodynamic technology in connection with such a powerplant." "...the construction, operation and maintenance of a magnetohydrodynamic component of capacity of no less than fifty megawatts of electric power in connection with the existing electric powerplant referred to in paragraph .." (above).	(2) (in Phase 2) design, construct and operate an integrated, coal-fired, combined cycle system of about 80 MW thermal power input that will be cost-shared with the private sector. The integrated system test will make optimum use of existing components and facilities.
SCHEDULE	SCHEDULE
"Competitive Bids. - Within one year after the date of the enactment of this Act the Secretary shall select the parties to the agreement under this section competitively, based on the bids available on the date thirty days prior to selection." "...a target date of January 1, 1992 for operation of the completed facility;"	The Department will submit an MHD transition plan and program plan to Congress in June 1984. The transition plan will include details for transitioning the MHD program from the current or historic approach to the two-phase, multi-year, cost-shared program described earlier. The program plan will include the program's goals, objectives, description of the effort, outyear budgets, and management approach.

"...set forth specific goals for the program, including a target date of 1992 for routine operation in connection with an existing electric powerplant of a proof of concept demonstration facility incorporating magnetohydrodynamic components."

BUDGET

"Authorization. - There is hereby authorized to be appropriated to the Secretary for the fiscal years ending September 30, 1985, and September 30, 1986 such sums as may be necessary to achieve the purpose of this Act."

BUDGET

Budget Request:	($ in thousands) FY 1984 Approp.	FY 1985 Request
Magnetohydrodynamics	$30,000	$17,800

Of the $17,800,000 requested, $10,800,000 is to conduct the Phase 1 MHD scientific research program and $7,000,000 would be used to initiate the Phase 2 efforts assuming significant private sector cost-sharing.

COST-SHARING

"...an adequate program of research, development and demonstration of magnetohydrodynamic technology will require an increased commitment by the Federal Government."

"...authorize the Secretary of Energy to make financial commitments to, and to enter into a cooperative agreement with private firms for the financing of a proof of concept demonstration of magnetohydrodynamic technology;"

"...assumption by the Federal Government of no more than 60 per centum of project costs under this section;" (i.e., the demo).

COST-SHARING

Government involvement in Phase 2 is contingent upon broad industry participation and significant cost-sharing (e.g., 50 percent Government/50 percent private sector). In the event that limited cost-sharing is obtained from industry, the scope and/or schedule of the Phase 2 program would be adjusted accordingly. Furthermore, the total absence of a cost-sharing commitment will result in the elimination of the planned Phase 2 effort and application of the $7,000,000 for Phase 2 instead to termination costs associated with phase-out of Departmental efforts in which the Component Development and Integration Facility (CDIF) would be mothballed and the Coal-Fired Flow Facility (CFFF) would be shut down. The DOE annual cost-share for this multi-year, cost-shared effort is anticipated to be approximately the same level as the FY 1985 request.

INTERNATIONAL COOPERATION

"International Cooperation. - The Secretary shall seek to enter into

INTERNATIONAL COOPERATION

The DOE R&D program for MHD has also been cooperating with the USSR, the Netherlands international cooperative agreements for the conduct of magnetohydrodynamic research and development of mutual benefit to the parties to any such agreement that the Secretary determines will further the purposes of this Act."

and Poland. Major U.S. hardware components were used and tested in facilities in both the USSR and the Netherlands, and the Poles were participating in a joint combustor test program with DOE. U.S. components were installed in test facilities in both the USSR and the Netherlands.

Concerning the cooperative agreement with the USSR, DOE (in accordance with the President's statement on Soviet sanctions of December 20, 1981) did not extend the Joint US-USSR Energy Agreement when it expired on June 28, 1982, and is now seeking the retrieval of its hardware loaned to the Soviets. The DOE-Polish MHD program under the US-Poland Joint Fund has been suspended.

Negotiations associated with the expiration of the USSR Cooperative Program on MHD are being coordinated with the State Department and other appropriate agencies through the Office of the DOE Assistant Secretary for International Affairs and Energy Emergencies.

TECHNICAL REVIEW PANEL FOR MHD

"Establishment of Panel. - Within ninety days after the date of the enactment of this Act, the Secretary shall establish, and with the concurrence of the Energy Research Advisory Board shall appoint at least seven members to, a Technical Review Panel for Magnetohydrodynamics."

"The panel under subsection (a) shall report annually to the Energy Research Advisory Board."

TECHNICAL REVIEW PANEL FOR MHD

No Provisions.

Senate Committee on
Energy and Natural
Resources (Johnston)
May 1, 1984

MHD

Question 5: Wouldn't it be helpful to enact a definite program for MHD development with stable funding, agreed-upon goals and milestones, and an objective oversight mechanism? Please provide the Committee with a list of amendments desired by the Administration in order to obtain your support for the legislation.

Answer: We are currently preparing a detailed program plan for submission to Congress in June 1984. The plan will propose a multi-year effort with clearly defined goals, objectives, milestones and administrative controls. The plan will contain sufficient flexibility to guide the program regardless of potential future technical uncertainties and budgetary constraints. We do not anticipate a need for special legislation for the MHD program.

From Dwain Spencer
EPRI

Response to Questions Posed By
Senators Domenici and Warner

1. Q. In reference to the Component Development Integration Facility (CDIF) in Montana, EPRI has contributed to MHD development by solely-funding the DC-to-AC power inverter development and construction. Presumably this inverter technology will be of great interest to all utilities in the future with general DC to AC conversion requirements. However, in any of the DOE-sponsored MHD projects at CDIF, the Coal Fired Flow Facility (CFFF) or AVCO-Everett Research Labs, has EPRI funded or intend to fund basic R&D related directly to the combustion process of the topping-cycle rather than an end-use technology?

A. EPRI has identified the consolidation circuitry, DC to AC power inverter, and power conditioning circuitry as key technologies to maximize the power extraction from the MHD channel. In addition to the development of the inverter for the CDIF, EPRI has funded additional R&D to develop second generation, improved consolidation circuitry and power conditioning systems. We expect that this will continue to be our primary area of emphasis.

In addition, EPRI has funded numerous systems and plant engineering and economic evaluations to assess the potential for OCMHD systems. Recently, we have decided to undertake an evaluation of a coal gasification-MHD combined cycle power plant. We believe that such an approach reduces the technical development risk associated with MHD systems by:

1) Utilizing proven coal gasification technology and gas cleanup processes to produce a clean fuel for firing in the MHD channel (very similar to firing natural gas as is being practiced in the Soviet Union).

2) Eliminates channel exposure to molten slag.

3) Benefits from the ability to use enriched air combustion systems, since an on-site oxygen plant could be utilized for both the coal gasification process and combustion air enrichment, eliminating the need for a high temperature air heat exchanger.

4) Eliminates the need for seed chemical regeneration since the sulphur species in the coal would be removed upstream of the MHD channel.

5) Eliminates any potential need for scrubbing of the plant flue gas, should the potassium carbonate to potassium sulphate conversion not be effective enough to meet air emission standards.

If this improved cycle shows promise of being economically competitive with other advanced coal systems, e.g., coal gasification-combined cycle power plants, EPRI may support combustor development necessary to effectively integrate such a system with an MHD channel. However, we do not intend to fund any combustor development for direct coal fired MHD channels.

2. Q. In view of the large Soviet MHD program which is presently constructing a 500 megawatt (electric) plant and has decided to make exclusive use of natural gas despite its large coal reserves (estimated to be 3/4 of our reserves); does EPRI believe that the Soviet engineers have uncovered any major technical or reliability problems with coal-fired MHD?

A. We do not believe that the Soviets have uncovered any fundamental limitations for direct coal fired systems, however as explained above, it is clearly easier and probably more reliable to use natural gas or clean Syngas from coal to fire the MHD plant. We suspect that the Soviets neither have the experience in developing coal combustors which could be utilized with MHD channels, nor the ability to separate and regenerate the potassium seed material from the ash.

Mr. Spencer, you have provided an excellent outline of the Electric Power Research Institute's commitment to fostering the advancement of coal technology.

1. Q. How do you picture the partnership between private industry and the government for the three funding phases described in S. 1925?

A. During the last ten years, EPRI has worked very closely with both the federal government and private industry to develop and demonstrate key advanced coal technologies. The primary approaches which we have developed are Cooperative Agreements among private sector organizations and the government, and funding "partnership" arrangements among private sector interested parties. We definitely believe that both types of relationships will be necessary in the future if we are to develop a broad technical base from which we could spawn a commercial synfuels and advanced coal industry on a timely basis.

Since most process developers wish to establish a proprietary business position relative to their individual technologies, I believe that EPRI and the federal government can be most effective in supporting pilot scale and demonstration facilities. In this way, the private sector can maintain ownership of their technical patents and knowhow, but should be required to share royalty income with all funding parties, including the federal government; thus repaying the taxpayer for his valuable venture capital. Of course, the major repayment to the taxpayer is a more stable economic condition in our country, i.e., dependence on domestic energy resources not foreign energy resources and the jobs which such an industry would produce.

In addition, the federal government can play a significant role through both DOE and the NSF in supporting more exploratory research which can lead to fundamentally new processes and technology improvements.

Finally, I continue to believe that the role of the Synthetic Fuels Corporation is crucial to get the first commercial scale plants on line as quickly as possible. This may necessitate broadening the authority of the SFC, but financial risk sharing on first commercial units appears to be necessary to obtain the private sector commitments to these plants in light of todays oil and gas prices.

2. Q. What kind of financial commitment is the electric power industry willing to make?

A. The electric power industry, primarily through EPRI, is planning to commit $100 to $150 million annually over the next five years for advanced coal technology, including synthetic fuels R/D&D. Over this five year period, the total utility funding R/D&D would be comparable to the level of funding proposed under S1925. By coordinating our R/D&D planning with the government and other private sector organizations, I believe we could develop a broad stable of technologies available for commercial order by the late 1980s or early 1990s.

In addition, I believe that we will soon see initial electric utility commercial commitments to integrated coal gasification combined cycle power plants, once full scale operating data, such as we will obtain from our Cool Water project, is in hand. However, even with the Cool Water data, there will be significant financial risk associated with these first commercial plants; therefore government risk sharing through the SFC or an alternate approach will likely be required.

Follow-up Q&A from Domenici

QUESTIONS FOR MR. McELWAIN

1. In the written testimony you mention that "There are no technological breakthroughs required to proceed with this promising conversion process (of MHD)." However, both the Gilbert/Commonwealth Report ("MHD Program Evaluation") and the Argonne National Lab Report ("Current Status of MHD Technology") list the areas of seed regeneration and the high temperature air heater as being relatively unproven with little or no research and development accomplished to date. Please explain how these two subsystems have been evaluated by Montana Power Company and what efficiency or economic penalties would be associated with alternatives such as a large oxygen-enriched air intake system.

   Answer: Seed Regeneration - I perceive the seed regeneration plant to be an engineering problem. The reconversion of potassium sulfate to potassium carbonate can be accomplished by several known chemical processes. The concern is which process to use. Laboratory scale tests are underway to establish the optimum candidate process for continued experimental study. At least one of the processes being considered, i.e., the formate process, was a commercial process at one time in Germany. Thus, the goal is to identify which process maximizes potassium carbonate converstion while minimixing plant costs (outlay/operation) and potassium loss.

   High Temperature Air Heater (HTAH) - Direct fired, high temperature air heaters are beyond the current state-of-the-art because of inadequate heater materials. Thus, it is generally accepted that all near term (and probably intermediate term) MHD plants would utilize an intermediate temperature air heater that heats oxygen enriched air. A worst case analysis, done by AVCO Everett Research Laboratory for DOE[1], indicated a 4.4% reduction in overall plant efficienty would occur (this was comparing an early commercial plant with a mature plant). However, this study also indicated that even with this efficiency penalty, an early commercial MHD plant would still be 9.6% more efficient than a conventional steam plant with a wet lime scrubber. Many scientists believe the efficiency losses will be much less. The many technology assessments on oxygen enriched MHD show that the MHD plant is still more efficient and the cost of electricity less than for a conventional coal-fired plant. The important point is that HTAH is not needed to prove the technology nor to make MHD competitive. When HTAH are developed, it will give MHD an even greater efficiency advantage. The Wright Brothers didn't invent the 747 at Kitty Hawk.

[1] Results from Conceptional Design Study of Potential Early Commercial MHD/Steam Power Systems, F. Hals, et al., 19th SEAM, Tullahoma, TN, June 1981.

2. In your written testimony you mention that the Gilbert/Commonwealth study ("MHD Program Evaluation") completed in 1983 for DOE recommends "larger proof of concept plants, preferably as an add-on to a commercial steam plant." However, the basis of the conclusions found by this study is that Gilbert recommends first a demonstration of the MHD components at the 50 MW thermal level, and then if this is successful to be followed by a 150 MWt(50MWe) demonstration plant as a phase 2 effort. Please explain Montana Power Company's position with respect to the general rule-of-thumb that new plants should be scaled-up by a factor of 3:1 (maximum), as followed by a number of utility consultants and architect/engineer firms.

Answer. Scale-up - Scale-up risks vary from component to component and on the interaction between components. Each individual risk and the composite risks must be evaluated to determine the reasonableness of a scale-up. The physics of the processes and the maturity of the technology have substantial impact on scale-up assessments. There are also financial risks associated with any scale-up and will generally be the deciding factor on how far one is willing to go.

In general, utilities are more conservative than your letter implies, even for mature plants. However, the risk criteria for scale-up are different in a research and development program than in commercial plants. The MHD proof-of-concept facility being considered is still in the development stage, where historically, the greater risks of scale-up are assumed, an 8:1 is not uncommon, e.g. TVA fluidize bed combustor development, 20 MW scaled to 160 MW. It would seem more reasonable to me to use a larger scale up factor at the development level (e.g., 5:1) and then a smaller factor in the commercialization (e.g. 2:1) rather than the Gilbert/Commonwealth Study of 3:1 and then 3.3:1 in the commercialization step. The significant MHD advancements to date, and the near-term information to be gained in the continued development program, seem to justify the approach of the larger proof-of-concept facility from both the technical and financial perspective. This parallel effort of the component development directed to the proof-of-concept retrofit should optimize the knowledge base and its application.

A retrofit in an existing commercial location seems to be the best alternative to allow for cost sharing, minimal cost investment by the federal government, and minimizing the development time to demonstrate commercial viability of MHD.

3. In the oral testimony, you have indicated that Montana Power Company is proposing the placement of an MHD topping cycle unit as a retrofit on the existing 60 MWe "Bird" gas-fired plant, and that the temporary use of the Bird plant represents a contribution from Montana Power. Would the Montana Power Company explain for the record whether this contribution in the form of existing hardware is to be supplemented by investment capital capable of funding new R&D, and if so, what would be the approximate net value of the intended funds?

Answer. The Montana Power Company's offer of the Frank Bird Plant as the retrofit site for the proof-of-concept MHD Integrated Test Facility was not temporary. The Frank Bird Plant would be dedicated to this MHD retrofit project with no long-range plan to return it to its present gas-fired peaking plant capability.

The facility and availability of the site should provide significant savings to the DOE/MHD Development program.

Supplemental funding of an appropriate program that advances the MHD technology would certainly be considered by the Montana Power Company.

MHD INDUSTRIAL FORUM
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MDH INDUSTRIAL FORUM'S
Response To Questions From The Committee On
Energy Research and Development
United States Senate
9 May 1984

Question 1.

During a visit to the Soviet Union by members of the U.S. MHD community in September 1983, Academecian Schiendlin, Director of the USSR High Temperature Institute, said a 1200 MW Thermal Plant is scheduled for service in the later 1980's. Dr. Schiendlin indicated that they have ample natural gas for the immediate future, however, a shortage of gas can be foreseen at a later date. Therefore, plans call for developing a coal-fired MHD unit.

Question 2.

To date about 10% of the total U.S. investment in MHD development has come from non federal government sources including institutions such as EPRI, state governments, utility companies and industrial firms. Recently the Montana Power Company offered a power plant for use in the DOE program. Consequently the MHD Forum has every confidence that non federal funding will continue to be available.

In recent testimony DOE Assistant Secretary William Vaughan told Congress that the departments opening negotiating position will be to ask for 50% private funding. We believe non federal government funding will be more than 10% but less than 50%.

The exact amount cannot be realistically estimated until a plan, including costs and schedules, directed toward an identifiable

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commercialization time frame is completed by DOE.

Question 3.

As we said in the testimony, MHD component development has reached the point where integrated coal-fired testing of the power train components at the CDIF is appropriate. Downstream components are now undergoing coal-fired integrated testing at the CFFF. The next phase of engineering development requires integrating the MHD topping cycle with the steam bottoming cycle preferable on a utility site such as the Bird plant offered to DOE by Montana Power Company.

The major obstacle to the engineering program described above has been the Administrations funding level and lack of a clearly defined goal for commercialization.

APPENDIX II

Additional Material Submitted for the Record

MAX BAUCUS
MONTANA

WASHINGTON, D.C.
(202) 224-2651

MONTANA TOLL FREE NUMBER
1-800-332-6106

United States Senate
WASHINGTON, D.C. 20510

April 10, 1984

The Honorable Pete Domenici
Chairman
Subcommittee on Energy Research
and Development
Committee on Energy & Natural Resources
Room 317, Dirksen SOB
Washington, D.C. 20510

Dear Senator Domenici:

The National Coal Science, Engineering and Technology Act is an important step towards providing a secure energy future and a clean environment through a strong federal commitment to basic research. With minor modifications to prevent the exclusion of Western coals from this research effort, and to recognize MHD as one of the technologies provided for in this program, I support S. 1925. I am also a co-sponsor of S. 1278 and enthusiastically support it.

For these reasons, I would like to ask that you include my written testimony in the record of the hearing on April 9, 1984, and consider the changes proposed therein when marking up the Coal Science Act. Thank you for your attention to this matter.

With best personal regards, I am

Sincerely yours,

Max Baucus

STATEMENT OF SENATOR MAX BAUCUS

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
S. 1278, S. 1925
April 9, 1984

Mr. Chairman, members of the committee, coal is the key to a secure energy future for this country. But coal is a dirty fuel!

This nation is blessed with vast coal resources. Those resources provide a secure source of energy that could allow the country's economy to continue to grow, but only if we can find a way to burn coal cleanly. We will not have sound economic growth if it is at the expense of the health of the people of this country and the environment.

We can have a secure energy future and a clean environment but only through a strong federal commitment to basic research. Both the National Coal Science, Technology, and Engineering Development Act and the Megnetohydrodynamics Research, Development and Demonstration Policy Act take significant steps to fulfill this need.

S. 1925, the National Coal Science Act, is another step in that direction. As an energy consuming nation, we need to know how to burn coal efficiently, cleanly, and reliably. This legislation will accelerate research and development in the government, university and private sectors to achieve commercially proven coal-cleaning, combustion and coal conversion technologies.

Coal Research

What is needed is:

(1) A massive effort to support the necessary research and identification of how contaminants occur in coal.

(2) An understanding of the process chemistry/identification technology needed to extract harmful elements, and

(3) The engineering development for proof of process to pilot plant scale operation.

These elements are critical if we are to simultaneously solve our need for inexpensive energy and the need to protect air quality. This legislation meets that test.

Acid Rain Concern

There is growing evidence coal burning is a major contributor to acid rain. Steps to address acid rain should be taken immediately. But immediate reductions of sulphur dioxide emissions are only part of a long-term solution.

This committee should be aware of the timetables being discussed as part of an acid rain control strategy. The acid rain control strategies calling for 10 to 12 million ton reductions in sulphur dioxide emissions will take ten years to be in place

At least one new technology, magnetohydrodynamics, could help reduce emissions by that amount. Many consider MHD development to be far off in the future. But I am confident that with a strong federal committment a 200 megawatt test MHD facility could occur by the end of this decade. MHD more than any other technology offers the hope of meeting both our energy needs in a cost-effective manner and controlling emissions of all air pollutants not just sulphur dioxides. It is the one technology that does not discriminate against the type of coal being burned.

The MHD process should be specifically identified in Section 5A of the bill. The program provided for in S. 1278 should be made a part of the National Coal Science, Technology and Engineering Development Act. A comprehensive program plan has been lacking in the MHD program in the past. The National Coal Development Bill could provide this focus. MHD offers the greatest hope to solve our need to gain additional electricity from coal burning and to protect the air.

RECOMMENDED CHANGES IN LEGISLATION

There are other changes needed. The legislation as drafted could be wrongly interpreted to exclude research into the use of Western coals. I could not support it, if this were the case. With minor modification Western coal concerns could be alleviated.

Another area of the national coal technology strategy which concerns me is that Section 5A(3) "pre-combustion cleanup" omits a very promising research strategy to clean and thermally upgrade low rank coal such as found in Montana. In order to support research into cleaning and thermally upgrading Montana's coal resources, the first sentence of Section 5A(3) should be amended to read "development of new and improved technologies that can clean coal and coal-derived gaseous and liquid fuels prior to use...This minor change will insure that a national coal strategy is directed at all of the coal resources of this country.

Conclusion

Let me close by saying the National Coal Science Technology and Engineering Development Act is a carefully thought out and comprehensive approach to understand coal and the burning of coal. It meets a clear national need to utilize our coal resources in environmentally sound ways. The reality of acid rain is a legacy of a failed coal research program. We can no longer afford the stop/go approach to coal research programs of the past.

Watching the ups and downs of the federal commitment to MHD research has made me acutely aware of the need for a consistent federal commitment to solving our energy needs in an environmentally responsible manner. This committee needs to take that first step to that future.

**BASIN ELECTRIC
POWER COOPERATIVE**
1717 EAST INTERSTATE AVENUE
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PHONE 701/223-0441 - TWX 910/877-2342

ATTENTION: Ron Richards

April 19, 1984

The Honorable Peter Domenici, Chairman
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources
Suite 360, Senate Dirksen Office Building
Washington, DC 20510

Dear Senator Domenici:

Basin Electric Power Cooperative is a consumer-owned regional cooperative supplying wholesale power to 118 rural electric member systems in eight states - Colorado, Iowa, Minnesota, Montana, Nebraska, North Dakota, South Dakota and Wyoming. Basin Electric operates 1,907 megawatts of coal-fired generating capacity in North Dakota and Wyoming and will complete construction on 880 megawatts of generating capacity in North Dakota by 1986.

The Cooperative's experience in operating these generating facilities leads us to believe that it may be possible for new technologies to be developed which will more efficiently use our Nation's coal resources, thus reducing our dependence on foreign oil and lessening our balance of payments deficit. The development of new, more efficient technologies would also help reduce the burden which consumers must bear as new generating capacity, built at higher cost, is brought on line to meet their needs.

Basin Electric's members have seen the cost of generating capacity increase from $136 per kw in 1966 to nearly $1,500 per kw for generating capacity to be completed in the late 1980's.

This is why we are extremely interested in the concepts embodied in S.1278 which provides for an accelerated program of research, development and demonstration with respect to the production of electricity from MHD, leading to the construction and operation of at least one major proof of concept demonstration project in connection with an existing power plant and for other purposes. Many years ago Basin Electric began to evaluate the potential for MHD and has long supported a program by the Federal government if commercial development is to be accomplished in a reasonable period of time.

Basin Electric's Production Department, which is responsible for the design, construction and operation of our existing

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The Honorable Peter Domenici, Chairman
April 19, 1984
Page 2

coal-fired power plants, continues to investigate developing technologies such as atmospheric fluidized bed combustion, integrated coal gasification combined cycle and magnetohydrodynamics. Our engineers feel that new technologies must be developed which will use our resources, particularly coal and water, more efficiently.

It is a generally accepted fact that it requires approximately ten years after the demonstration stage to develop a major new technology for commercial use. MHD has not even reached the demonstration stage yet, therefore, we believe the commercial utilization of this technology is quite far into the future. While MHD offers the potential for significantly more efficient fuel use, the economic risks are too great for the utility industry to seriously pursue this technology without some form of assistance. Therefore, Basin Electric encourages a program at the level of the Federal government to pursue the development of a demonstration MHD project. Without such a program, the commercialization of this technology will continue to be pushed far into the future.

Therefore on behalf of Basin Electric Power Cooperative, we commend you for holding a hearing on S.1278 and thank the sponsors, Senator Melcher and his associates, for introducing this very farsighted bill. We urge that S.1278 be approved by the Subcommittee and the full Committee as soon as possible.

Sincerely

James L Grahl

James L. Grahl

keg
cc: Senator John Melcher
Basin Electric Board of Directors

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Mid-West Electric Consumers Association, Inc.

EVERGREEN EXECUTIVE BUILDING
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April 17, 1984

Honorable John Melcher
United States Senate
Washington, D.C. 20510

Dear Senator Melcher:

I was delighted to learn that a hearing was held on April 9, before the Senate Energy and Natural Resources Committee on your MHD bill (S. 1278).

Since the mid-1960's, Mid-West has urged research and development for an evaluation of MHD as an advanced technique for generating electric power from fossil fuels, and particularly from low grade coal.

For years, the members of our Association have expressed in their resolutions the view that MHD holds real promise of making a major contribution to wise use of an important resource, assisting the urgent effort to reverse the deterioration of the environment, and permitting electric utilities to supply the needs of their members or customers at low cost.

Because MHD holds so much promise of achieving results that are important to the United States, we consider it appropriate for the United States to partcipate financially in the development of the necessary technical competence.

MHD's potential for substantially increasing the efficiency of electric power generation promises to reduce electric power costs significantly, conserve coal supplies and diminish the adverse effects on air and water that accompany any fuel conversion process.

As a corollary we would expect the United States to make sure the benefits of the new technology are available to all on a suitable basis.

Mid-West enthusiastically supports your bill. There is a crying need for the United States to develop technology to get more kilowatt hours out of a ton of coal, so less heat will be wasted in the environment. MHD holds the promise.

Mid-West Electric Consumers Association, Inc. is the service organization of rural electric cooperatives, municipal utilities and public power districts located in the nine States of the Missouri River Basin. Our 350 member systems, representing 3,000,000 customers are electric utilities that are owned by their members.

I respectfully request this statement be included in the record in support of S. 1278.

Sincerely,

Fred G. Simonton

Fred G. Simonton
Executive Director

TO: Subcommittee on Energy Research and Development
of the Committee on Energy and Natural Resources

Statement in Support of S. 1925
The National Coal Science, Technology, and Engineering Development Act
Kaiser Aluminum & Chemical Corporation
April 18, 1984

Kaiser Aluminum & Chemical Corporation wishes to express its support for S. 1925, The National Coal Science, Technology, and Engineering Development Act.

We are a major producer of aluminum, with diversified operations in industrial and agricultural chemicals, oil and gas, international trading, real estate, and refractories. Our cost of producing aluminum (and, therefore, our competitiveness in this country and internationally) depends, to a very significant degree, on the cost of coal-fired electricity.

We commend Senator Byrd for authoring and introducing this measure. We share his belief in the wisdom of a program to accelerate the development of new and advanced technologies to allow for the expanded use of coal in an environmentally acceptable manner. We also support the direction of S. 454, the Senator's proposal to accelerate study of the acid rain phenomenon and, meantime, to provide grants for mitigating aquatic areas that have high levels of acidity.

In our opinion, the thrust of the two measures provides a forward-looking, cost-effective approach. We believe that the time and resources employed to intensively study the causes and effects of acid deposition are well spent. It would be a serious mistake to enact any of the acid rain control programs that are pending in Congress without having first resolved many of the scientific uncertainties and contradictions. The last thing industry and consumers need is an inadequately tested, prematurely

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(continued)

introduced control program that will add enormous costs without producing significant environmental benefit. There is time to be guided by scientific evidence and expertise rather than by emotional sentiment, however well-intentioned.

S. 1925 is important because it would complement scientific research already underway and would involve the university community and the private sector in addition to the scientific and technical resources available through the energy technology centers and the national laboratories. By setting goals and near-term timetables, it should prompt timely technological answers that will, at the very least, prevent costly mistakes.

It is very much in our country's best interest that coal's vast potential be developed. To the extent that this is done, jobs are created, economic growth is stimulated, and energy needs are secured. S. 1925 recognizes this potential and the fact that the foundation in coal science, process science, and engineering development needs strengthening.

The aluminum industry has a major stake in this issue and the issue of acid rain controls.

Aluminum smelters produce aluminum metal from alumina ore by using an electrolytic process that is both electricity dependent and electricity intensive. The production of aluminum is highly energy cost sensitive. Electric power rates and how they are determined have a direct impact on our ability to compete in international trade.

Electricity costs represent about one-third of the cost of producing aluminum. On average, it takes 7.5 kilowatt hours of

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(continued)

electricity to make a pound of aluminum. Based on 1982 data, the average U. S. cost of electricity for aluminum production was estimated to be 2.4 cents or 24 mills per kilowatt hour, and in the last year this cost climbed even higher. Our Free World competitors, in contrast, pay an average of 1.7 cents or 17 mills per kilowatt hour. Some foreign smelters, including Canadian smelters, pay as little as 3 mills. Foreign smelters thus already hold a large competitive advantage in terms of this major component of the cost of producing aluminum.

Approximately 60 percent of the aluminum industry's smelter capacity in the United States is located in the 31 states east of or bordering on the Mississippi. Ninety percent of that capacity depends on coal-fired electricity and will be directly affected by increased costs resulting from SO_2 reductions proposed in acid rain control proposals.

An analysis conducted by the Aluminum Association shows that proposed controls to reduce SO_2 emissions by 8 million tons could increase the cost of electricity to some aluminum plants in the 31-state region by more than 10 mills per kilowatt hour. This means an additional 7-1/2 cents per pound to the cost of producing primary aluminum.

One of the reasons we support S. 1925 is because of the damage that current acid rain control proposals would cause our company.

Kaiser Aluminum owns and operates an integrated aluminum smelter and rolling mill facility in Ravenswood, West Virginia. The cost of coal-fired electric power supplied to Ravenswood is approximately in line with the U. S. aluminum smelter average of 24 mills per kilowatt hour.

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(continued)

Based on the best information we can obtain, we estimate that an increase of 25 percent or more in electricity prices to Ravenswood would result from passage of pending acid rain legislation. An increase of this magnitude would seriously damage the competitive position and cause a loss of jobs not only at Ravenswood, where we employ approximately 2900 people at full operation, but also at fabrication plants in other states that receive metal from Ravenswood.

The Ravenswood facility constitutes Kaiser Aluminum's largest production complex in the world. The smelter portion was reactivated in the latter half of 1983 after an 18-month close-down due to excessive production costs. Kaiser Aluminum and the United Steelworkers of America negotiated major revisions of work practices and other agreements during this period to increase labor prouctivity and to return the plant to competitive status. Increases in Ravenswood's electricity rates approaching the magnitude estimated would nullify the labor productivity and other production gains made by Kaiser and the Steelworkers through sacrifices by both labor and management. The future of the Ravenswood smelter is unquestionably linked to coal-fired power and, thus, to the acid rain issue.

We firmly believe that more scientific research is needed into the causes and effects of acid rain and that S. 1925 represents a constructive supplement by setting a course for addressing the technological challenges raised by the acid rain issue.

We hope that the Congress will fully consider the merits of this proposal.

TESTIMONY OF JOHN R. SELLARS,
VICE PRESIDENT AND GENERAL MANAGER,
TRW ENERGY TECHNOLOGY DIVISION,
ENERGY DEVELOPMENT GROUP,
REDONDO BEACH, CALIFORNIA

BEFORE THE
SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

APRIL 9, 1984

Mr. Chairman and Members of the Subcommittee on Energy and Research and Development:

I am John Sellars, Vice President and General Manager of the Energy Technology Division of TRW, where our company's energy science, technology and development activities are centered. I very much appreciate the opportunity to share with you TRW's views on the vital issue of coal research and development as an essential ongoing national goal. I wish to comment on and endorse the Senate Bill 1925, introduced by Senator Byrd, to establish a national coal science, technology and engineering development program.

TRW has performed a leadership role in a significant number of coal technology research programs. In the area of coal combustion projects we are actively working on: 1) an advanced slagging coal combustor which will be economically retrofitted to both utility and industrial boilers presently burning gas and/or oil; 2) a high pressure slagging combustor for coal-fueled gas turbines; and 3) coal combustors for the magnetohydrodynamics program, which is the subject of Senate Bill 1278 introduced by Senator Melcher.

TRW also has programs in coal/water mixtures, coal gasification, coal preparation and post-combustion cleanup for sulfur emissions control. These coal research areas are all mentioned in Senate Bill 1925, and illustrated in the attached TRW brochure which I am submitting for the record.

We believe that coal can grow to become not only an alternate to presently popular resources of oil and gas, but a nationally dominant energy resource for the energy security of the United States. Coal's present and future importance can only be underlined by the international events which daily point to the vulnerability of the Persian Gulf and the volatile middle east oil import supply line.

It is, therefore, no accident that, for many years, TRW has been engaged in fossil fuel research and development. TRW's commitment to coal is shown by the amount of company funds we have spent in this research in the past few years; an amount in excess of $50 million. In fact, TRW constructed and operates its own Fossil Energy Test Site at our 2700 acre Capistrano testing facility in California. Built entirely with TRW's funds, this test site has been expanded several times, and will continue growing with TRW funding for several years to come.

TRW has also donated the use of one of the boiler facilities at its aircraft components plant in Cleveland, Ohio. We will conduct a long duration demonstration of a 40 million BTU per hour coal combustor there, which was also developed by TRW's private investment.

Under the auspices of the Department of Energy TRW is conducting extensive low NOX, SOX and ash removal tests on a 40 MBTU/H combustor at our Fossil Energy Test Site. The tests will use pulverized coal and coal/water mixtures, and enable the ultimate technology developed for industrial and utility users to address more challenging emissions and operating requirements.

Let me comment on the promise these coal technologies offer. In testimony I made made before the House Science and Technology Committee two years ago I said,

> "If we carry out these programs we have the possibility to learn how to clean coal until it behaves, truly, as a 'solid oil'. We can learn to turn it into liquids, even burn it in our automobiles, or we can turn it into electricity without polluting our atmosphere."

As a scientist I am convinced those are not idle promises, and that they represent attainable coal research and technology objectives. That is why I am pleased with Senator Byrd's effort to establish a national coal science, technology, and engineering development program. This program can accelerate our progress toward securing America's energy independence.

I am particularly pleased to see a section in the bill on engineering development included as a mechanism for proceeding from process science and engineering research to full commercialization. I've observed the tendency of our federal agencies to prematurely want to discontinue sponsorship of promising technologies long before they are ready for commercial development. Although well intended to protect tax dollars, that approach fails to appreciate the financial risks which inhibit private enterprise from taking an unproven idea to market. Section no. 6 of S.1925 should go a long way toward defining the cooperative fiscal roles of government and industry in the pre-commercialization phase.

In this same section of the bill the phrase "proof of concept" is used, referring to processes and systems of a significant scale. There are cases where a proof of concept can actually range down to a small scale experiment. Though generally larger than bench scale experiments, they may still be at a very early stage of the development, and thus, precede the size of a proof of concept referred to in the "Engineering Development Program."

For instance, TRW has discussed a "proof of concept" chemical coal cleaning plant with a capacity of five tons per day. The physical dimensions and investment in a plant this size is much smaller than one described in Section no. 6, where it says, "no more than 500 tons per day." Indeed, five tons per day is really a large scale bench experiment designed to overcome some of the flow problems inherent in the very small scale experiments being carried out at present.

I think it would be proper to consider smaller scale "proof of concept" experiments as part of the Engineering Research portion of the bill, to avoid excluding them due to mere semantics. Perhaps Senator Byrd would consider adding a phrase such as "Small scale proof of concept experiments are permitted under this section" in Section no. 5 on "Process Science and Engineering Research."

In closing, Mr. Chairman I wish to emphasize that S.1925 is needed to significantly accelerate coal research and the development of advanced concepts and technologies that will relieve our dependence on unstable foreign energy supplies.

Thank you for the time alloted to me to testify before your committee. I invite questions you may have about my testimony.

STATEMENT OF

JOHN J. KEARNEY
SENIOR VICE PRESIDENT
EDISON ELECTRIC INSTITUTE

TO THE

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

ON

S.1278 and S.1925

APRIL 18, 1984

My name is John J. Kearney and I am a Senior Vice-President of the Edison Electric Institute (EEI). EEI is the association of the nation's investor-owned electric companies. Its members provide approximately 76 percent of the electric power used in this country.

EEI appreciates this opportunity to submit a statement to the Subcommittee on Energy Research and Development of the Senate Energy and Natural Resources Committee regarding consideration of S.1925 and S.1278. We are encouraged by Congress' recognition of the value of long-term planning for research and development efforts relating to advanced coal utilization and conversion technologies.

During ~~1983,~~ electric utilities burned over 600 million tons of coal, or about 75 percent of domestic consumption. This represents a 40 percent increase in utility coal consumption over the last 10 years. By the year 2000, it is anticipated that utility use of coal will grow to over a billion tons per year. Currently, over 55 percent of our nation's electricity is generated by coal.

The technology for using coal to produce electricity is essentially the same as that used in the 1920's. That technology has reached the limits of its development with maximum power plant efficiencies of 35 percent.

If we are to continue meeting our national security and energy needs through increased usage of our nation's abundant reserves of coal, we must find ways to burn coal more efficiently, economically, and with minimum detrimental impact on our environment.

The proposals contained in S.1925 and S.1278 would help us meet that challenge.

The electric utility industry is committed to supporting research on numerous advanced coal utilization technologies. These efforts are described in testimony presented to this subcommittee by the Electric Power Research Institute.

Consistent and reliable federal financial support is vital to the success of long-term coal science research and development projects. Therefore, it is appropriate that government continue its role as a strong dependable partner in R&D efforts to advance our nation's efficient, economic use of coal.

Our industry believes that a consistent planned effort promoting the development of a variety of advanced coal technologies is in our nation's best interest. We encourage Congress to continue its efforts in this area to assure the most efficient and clean utilization of our nation's greatest energy resource--coal.

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